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LABADIE ENERGY CENTER
§316(a) REVISED FINAL DEMONSTRATION
DRAFT

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EXECUTIVE SUMMARY

The Labadie Energy Center (LEC) is a steam electric power plant located in Labadie, Missouri on the south bank of the lower Missouri River near River Mile (RM) 57 in Franklin County. The LEC has four generating units and a total net capacity of 2,580 megawatts (MW) and utilizes a once-through cooling water system withdrawing water from the Missouri River. The resulting heated effluent is discharged (via National Pollution Discharge Elimination System (NPDES) Permit MO-0004812, Outfall 001) to a 1,400-foot-long discharge canal and the adjacent navigation channel of the Missouri River.

The current LEC NPDES permit final effluent limitations became effective on August 1, 2018 and are based on a site-specific thermal model that establishes an effluent limitation of 0.95 for the Thermal Discharge Parameter (TDP), a calculated parameter used as an index of compliance with the Missouri Water Quality Standards ($MWQS_{t.}$) for temperature. The model established that an effluent limitation of 0.95 for the TDP value would ensure compliance with the $MWQS_{t.}$. The TDP limit incorporates a 5 percent margin of safety to ensure compliance with the $MWQS_t$ at the edge of the allowable mixing zone. Nevertheless, the potential for occasional, infrequent exceedances (less than one percent of the time on average based on existing data) of the $MWQS_{t.}$ for temperature exists during conditions of extraordinarily high ambient river temperature and/or extraordinarily low river flow leading Ameren to seek alternative thermal effluent limitations (i.e., a thermal variance from the otherwise applicable effluent limit for the receiving water body).

Ameren is proposing the following alternative temperature effluent limit to ensure continued operation of the LEC while, at the same time, assuring the protection and propagation of a balanced indigenous community in the lower Missouri River (LMOR):

- A TDP of greater than 0.95 will be allowed under conditions when the river flow is less than 40,000 cubic feet per second or ambient river temperatures are greater than 87°F;
- A TDP of greater than 0.95 will be allowed in no more than 6 percent of the days in any calendar year; and
- On any day where the TDP is greater than 0.95, the mixing zone must be less than 40 percent of the volume of the river as calculated by the equations in the permit.

This Demonstration uses a retrospective assessment to evaluate whether the LEC past and current operation has resulted in appreciable harm to the aquatic biota in the LMOR near the LEC and a predictive assessment to determine whether the proposed alternative effluent limits for temperature will assure the protection and propagation of the balanced indigenous community (BIC) of the LMOR.

Screening Results for Biotic Categories

Historical biological data collected in the vicinity of the LEC and from the LMOR were evaluated relative to the seven United States Environmental Protection Agency (USEPA) decision criteria and for each of six biotic categories to address the potential for impacts from LEC's thermal discharge. The evaluation indicated that the LMOR within the LEC study area successfully met the USEPA decision criteria for being considered an area of Low Potential Impact (LPI) for four of the six biotic categories, including the shellfish component of the benthic macroinvertebrate category. A summary of the rationale for LPI biotic categories is as follows:

- **Phytoplankton** - the Missouri River food web is detrital based. Phytoplankton have limited exposure to the thermal plume (less than 90 minutes). There is no evidence indicating that the LEC thermal discharge has caused, or has the potential to cause, a shift towards nuisance phytoplankton taxa.

- **Zooplankton and Meroplankton** - The Missouri River has a low standing crop of zooplankton. Zooplankton and meroplankton drifting downstream are exposed to the thermal plume for a limited duration (less than 90 minutes) due to the flow of the river and the thermal plume affects a relatively small proportion of the LMOR near the LEC (discharge flow is typically less than 5 percent of the river flow).
- **Habitat Formers** – The area in the vicinity of the thermal discharge is devoid of habitat formers due to the River's velocity, turbidity, and silty substrate and would remain so even if the LEC thermal discharge were removed.
- **Shellfish** - The shellfish component of the benthic macroinvertebrate assemblage occur only rarely in the vicinity of the LEC thermal discharge and, hence, has little potential for exposure to the thermal plume. During the current study, no live shellfish were observed either upstream or downstream of the discharge during the visual surveys. No threatened or endangered shellfish species were collected in benthic macroinvertebrate samples and no shells of threatened or endangered shellfish were observed in the visual surveys.
- **Other Vertebrates** - Non-fish vertebrate wildlife such as waterfowl have minimal and intermittent exposure to the LEC thermal discharge and are therefore not vulnerable to direct effects from the thermal discharge.

Hence, detailed analysis of prior appreciable harm was limited to the two remaining biotic categories: fish and benthic macroinvertebrates.

Retrospective Assessment

As presented in this Demonstration, the Retrospective Assessment includes a spatial component comparing communities in the area exposed to the thermal discharge with those in a reference area representing the BIC to evaluate whether appreciable harm has occurred to the fish and benthic macroinvertebrate components of the BIC due to the LEC thermal discharge. A temporal component (fish only) is also included to evaluate changes in the BIC over time.

Evaluation of Prior Appreciable Harm to Fish

Spatial analysis of the data collected during the recent two-year biological monitoring program shows that the LEC thermal discharge is not causing appreciable harm to the fish assemblage. Overall, the fish assemblage abundance, composition, diversity, and abundance of heat tolerant species were similar between the Upstream Reference, Thermally Exposed, and Downstream zones. A "standardized difference" analysis of the combined spatial data incorporating all the metrics evaluated was conducted to compare the Upstream Reference zone to Thermally Exposed zone and to the Downstream zone over all seasons. The distributions in all instances were centered near 0 with mean differences smaller than the standard error indicating that the differences are not likely to be biologically meaningful.

The temporal analysis comparing electrofishing data collected during historical and current studies at corresponding sampling sites at the LEC shows that the LEC thermal discharge has not caused appreciable harm to the fish assemblage. Many of the metrics evaluated (e.g., abundance, diversity, community composition) were either similar between historical and present data or demonstrated similar temporal trends in both the Upstream Reference and Thermally Exposed zones indicating that any observed differences are not due to the LEC thermal discharge. A "standardized difference" analysis of the temporal data for the Upstream Reference and Thermally Exposed zones had positive mean differences indicating some improvement in ecological metrics over time in both zones.

Taken together, the results from the spatial, temporal, and "standardized difference" analyses indicate that there has been no appreciable harm to the fish component of the aquatic community resulting from the LEC thermal discharge.

Evaluation of Prior Appreciable Harm to Benthic Macroinvertebrates

Spatial analysis of the data collected during the recent two-year biological monitoring program shows that the LEC thermal discharge is not causing appreciable harm to the benthic macroinvertebrate assemblage. Benthic macroinvertebrate densities were variable between zones, gears, and seasons but did not show patterns consistent with a thermal effect. Overall, the total number, density, diversity, and abundance of sensitive taxa was similar between Upstream Reference, Thermally Exposed, and Downstream zones for both drifting organisms and infaunal organisms. The Discharge Zone, where sampling was conducted within the unmixed thermal effluent and immediately downstream of the confluence with the Missouri River, as would be expected, exhibited lower numbers in all three categories for both collection gears.

A "standardized difference" analysis of the combined spatial data incorporating all the metrics evaluated for each collection gear was conducted to compare the Upstream Reference zone to Thermally Exposed zone and to the Downstream zone over all seasons. The mean differences in both zone comparisons were slightly negative. However, the magnitude of the shifts is small and about the same as the standard errors suggesting the shifts are not large enough to be biologically meaningful.

In addition, if any of the potential adverse effects were due to the thermal discharge, one would expect the shift from the Upstream Reference zone to Thermally Exposed zone comparison to be greater than the shift for the Upstream Reference zone to Downstream zone comparison. Since the values are nearly identical, the analysis suggests that any potential minor adverse effects are not due to the LEC thermal discharge. The spatial and "standardized difference" analyses indicate that there has been no appreciable harm to the benthic macroinvertebrate component of the aquatic community resulting from the LEC thermal discharge.

Overall, the results of the retrospective assessments show that there has been no appreciable harm to the BIC resulting from prior LEC thermal discharges.

Predictive Assessment

The focus of the predictive assessment is on the relatively rare events (<1 percent of the time) when the TDP limit is greater than 0.95 and the $MWQS_{t}$ for temperature could be exceeded. The potential thermal exposures during these rare events were assessed using three-dimensional hydrodynamic modeling (FLOW-3D) results and data from two days reflecting the most extreme conditions over the 17-year data record during the most biologically active periods of the year. Actual river and discharge flows and temperatures from June 22, 2006 ("June Model') were used in the model reflecting the most extreme conditions during the spring spawning and nursery period. Similarly, actual river and discharge flows and temperatures from July 21, 2006 ("July Model") were used reflecting the most extreme conditions during the high temperature period in summer.

In both cases, the resulting plume hugs the south shore immediately downstream of the discharge with the plume extending only part way across the LMOR. For the June conditions, temperatures above 90°F were limited to areas within one mile of the discharge and were restricted to areas along the south shore of the LMOR. For July, temperatures above 90°F were limited to areas within about 5.5 miles of the discharge and principally in the southern half of the LMOR.

Exposure of Drifting Organisms

In the June 2006 model run, the background temperature was 83.58°F and only 23 percent of virtual particles "released" by the model along a transect upstream of the LEC discharge were exposed to temperatures in excess of the $MOWQS_t$. In the July 2006 model run, the background temperature was higher at 88.88°F but less than 18 percent of the virtual particles were exposed to temperatures in excess of the $MOWQS_t$. The resulting time vs temperature plots reveal a rapid decline in exposure temperatures within the first 20 to 30 minutes after encountering the discharge, due primarily to turbulence and the high volume of river flows compared to plant discharge flows within the LMOR leading to rapid mixing.

Temperature measurements at the downstream end of the Zone of Initial Dilution (ZID) of the discharge plume revealed that most of the time temperatures were 4°F or less above ambient. Further, only 10 percent of the measurements were greater than 6°F above ambient and all of these were during the coldest periods of the year with little biological productivity.

Representative Important Species

Representative Important Species (RIS) were selected to reflect the biotic components of the indigenous community that were not deemed to be low potential for impact. The following RIS were selected for this predictive assessment:

RIS	Rationale
Channel catfish	Recreational species
Emerald shiner	Important food chain species
Gizzard shad	Important food chain species
Pallid sturgeon	Endangered species
Walleye/sauger	Recreational and temperature sensitive species
White crappie	Recreational and temperature sensitive species

Heat Shock

The life-history characteristics of some RIS serve to limit their potential exposure to the LEC thermal discharge. For those early life stages that would be exposed to the thermal discharge while drifting with the current, exposures were shown to be of relatively short duration (e.g., $\leq$80 minutes). Exposure temperatures at, or exceeding, the thermal limits of early RIS life stages were present in only a small proportion of the LMOR (typically less than 1 percent) and for very short durations (typically less than 30 min.). In addition, temperatures above thermal heat shock limits would be experienced less than 25 percent of the time for all RIS under worst-case conditions. Comparison of the model results to the thermal tolerance literature values for the early life stages of the RIS show that there is little likelihood of heat shock mortality to any of the RIS as a result of the LEC thermal discharge.

Cold Shock

Information needed to assess the potential for cold shock associated with the complete shutdown of all units at the LEC was available for three of the six RIS selected for this assessment. In all cases, the lower incipient lethal temperatures (LILT) were less than the temperature exposures that would occur with complete shutdown of all units at the LEC. Further, the likelihood that all units would be simultaneously shut down at the LEC is exceedingly low. Therefore, there does not appear to be any potential for mortality associated with cold shock at LEC.

Indirect Effects on Reproduction and Development

Temperatures to which the RIS could potentially be exposed in the worst-case scenarios were compared to the literature-based thermal tolerance data for growth and reproduction for each RIS. In all cases, reproduction and growth would either not be affected or would be accelerated leading to slightly earlier reproduction and greater growth. Therefore, there are no adverse effects expected due to exposure to the elevated temperatures from the LEC thermal discharge.

Effects on Habitat and Migration

For four of the six RIS (channel catfish, emerald shiner, gizzard shad, and white crappie) the entire cross-section of the water column is available as a zone of passage under typical conditions. Under worst-case conditions the cross-sectional area would be reduced for gizzard shad and white crappie, however approximately half of the cross-sectional area in the vicinity of the LEC would still be available as a zone of passage.

For walleye/sauger, both cool water species, ambient temperatures frequently exceed their avoidance temperatures during summer, however their use of the LEC vicinity at this time of the year is limited. As ambient temperatures approach their avoidance temperatures, these species would be expected move to cooler areas upstream or to other areas of thermal refuge. Their use of areas near the LEC is primarily during spawning migration in late winter and early spring when exposure temperatures should be substantially lower than reported avoidance temperatures indicating no potential for blockage of migration.

While estimates of avoidance temperatures for pallid sturgeon are not available, the fact that this species would most likely be found in deeper channel area with little exposures to elevated temperatures, suggests little potential for migratory blockage

Master Rationale

Under § 316(a) of the Clean Water Act, a permittee may obtain an alternative thermal effluent limitation upon establishing, to the satisfaction of the permitting agency, that its thermal discharge, combined with other potential impacts on the aquatic biota, will assure the protection and propagation of the BIC in and on the receiving water body.

Indicators of Appreciable Harm

USEPA's § 316(a) technical guidance provides a number of criteria to evaluate in demonstrating the absence of appreciable harm, as follows:

1. Presence of all trophic levels
2. Presence of necessary food chain species
3. Diversity
4. Capability to sustain itself
5. Lack of domination of pollution (heat) tolerant
6. No increase in nuisance species
7. Increase or decrease of indigenous species
8. No decrease in threatened and/or endangered species
9. No habitat exclusion due to temperature
10. Maintenance of a zone of passage

11. Change in commercial or sport species
12. No habitat former alterations
13. Magnitude and duration of any identifiable thermal effects
14. Sublethal or indirect effects
15. No thermal effects on rare or unique habitats
16. Presence of critical function zones within thermally exposed areas
17. Trends in the aquatic community
18. Interaction of the thermal discharge with other pollutants

These criteria focus the determination on population and community impacts. Still, demonstrating that the BIC is or will be assured in any receiving water body can be problematic since no operational definition of "balanced" is provided by the USEPA, and no quantitative standard for balance has ever been proposed. In this case, a weight-of-evidence approach using multiple lines of evidence for the LEC is used to evaluate the USEPA criteria and determine whether the thermal discharge has caused appreciable harm to the BIC in the receiving waterbody.

Weight of Evidence Rationale for No Prior Appreciable Harm

Each of the appreciable harm criteria are addressed below using the results of the screening analysis and retrospective and predictive assessments conducted as part of this Demonstration.

1. *Presence of all trophic levels*

The composition of the aquatic community in the Thermally Exposed and Downstream zones shows the presence of the necessary trophic levels similar to the Upstream Reference zone indicating that the structure of the community has not been adversely affected by exposure to the LEC thermal discharge.

2. *Presence of necessary food chain species*

The composition of the aquatic community in the Thermally Exposed and Downstream zones shows the presence of the necessary food chain species similar to the Upstream Reference zone indicating that the structure of the community has not been adversely affected by exposure to the LEC thermal discharge.

3. *Diversity*

Diversity profiles for the spatial and temporal (fish only) analyses for the both fish and benthic macroinvertebrates show that diversity profiles for both assemblages were similar to those in the Upstream Reference zone. Thus, the data demonstrate that diversity has been maintained over time and has not been adversely affected as a result of exposure to the LEC thermal discharge.

4. *Capability to sustain itself*

The results of the predictive and retrospective assessments demonstrate that the biological community near the LEC is self-sustaining. The predictive analysis demonstrated the absence of mortality and negative effects on growth and development as a result of exposure to the LEC thermal plume for all life stages of the selected RIS. This is supported by the retrospective analysis which showed the presence of multiple year classes of fish present and no substantial shifts in the fish community over time and no substantial changes in the current fish or benthic macroinvertebrate assemblages between the Upstream Reference and Thermally Exposed zones.

5. *Lack of domination of pollution (heat) tolerant species*

Fish and benthic macroinvertebrate assemblages were dominated by heat tolerant taxa of similar abundance in the Upstream Reference, Thermally Exposed, and Downstream zones. The temporal analysis of the fish data show that heat tolerant taxa have not increased in the Thermally Exposed zone over time and remain at similar proportions as in the Upstream Reference zone. Pollution/heat tolerant taxa have not increased as a result of exposure the LEC thermal discharge.

6. *No increase in nuisance species*

Species of Asian carp, including bighead, silver, and grass carp, are among the most notable non-native, nuisance species now present in the LMOR. The invasive Asian carp have become increasingly abundant in the vicinity of the LEC and the LMOR through a process of range expansion following their accidental escape into the Mississippi River basin and not due to the LEC thermal discharge.

7. *Increase/decrease of indigenous species*

River-wide modifications and loss of the natural riverine flow regime and habitats have greatly influenced the abundance of native species and affected the overall composition of the fish community resulting in the abundance of non-native species becoming greater than that of native species. These changes to native fish populations have occurred in response to irreversible river modifications that are unrelated to the LEC thermal discharge and would have resulted in the absence of the discharge.

The temporal retrospective analysis shows that the fish assemblage represented in electrofishing samples was similar in both the Upstream Reference and Thermally Exposed zones over time demonstrating that the LEC thermal discharge has not resulted in a decrease, locally or in the LMOR, of indigenous species.

8. *Decrease in threatened and/or endangered species*

The pallid sturgeon is the only federally endangered species potentially in the vicinity of the LEC. Available data suggest that this species is declining throughout the Missouri River due to factors such as upstream dam and reservoir construction, reduced river water velocities and low bottom dissolved-oxygen levels. The data demonstrate that the river-wide decline of pallid sturgeon has nothing to do with LEC's thermal discharge. Further, there is no evidence that LEC's thermal discharge has eliminated designated critical habitat areas for pallid sturgeon in the LMOR.

9. *Habitat exclusion due to temperature*

Under typical and maximum plant operation little to no habitat exclusion is expected for any of the RIS. Walleye and sauger are not typically found in the LMOR near the LEC during the summer period since ambient river water temperatures are above their thermal tolerance limits. Any periods of habitat exclusion would be brief and limited to small areas just downstream of the discharge. Ample alternate habitat exists for all potentially affected species. The predictive assessment demonstrates that substantial areas of habitat would not be excluded for any RIS.

10. *Maintenance of zone of passage*

Under typical plant operation, five of the six RIS (channel catfish, emerald shiner, gizzard shad, white crappie, and pallid sturgeon) would have the entire river cross-section available as a zone of passage. Walleye/sauger are not typically found in the area of the LEC discharge during the summer when ambient temperature approach and exceed their avoidance temperatures. At other times of the year, the zone of passage for walleye/sauger would be maintained. Under worst-case conditions, the zone of passage for gizzard shad and white crappie would be reduced but they would still have approximately half of the river cross-section available as a zone of passage.

The predictive assessment demonstrates that a zone of passage would be maintained at all times for all RIS.

11. Change in commercial or sport species

The retrospective spatial analysis shows the abundance of game fish is approximately equal in the Upstream Reference, Thermally Exposed, and Downstream zones over all seasons and gear types. The temporal analysis shows that there was a slightly higher abundance of game fish collected in the historical Thermally Exposed zone electrofishing study than the present study. These analyses demonstrate that the LEC thermal discharge has not resulted in a change or decrease in the number of sport or game fish.

12. No habitat former alterations

The screening analysis concluded that the LMOR near the LEC was found to be an area of LPI for habitat formers due to the river's velocity, turbidity, and silty substrate which were limiting factors to the colonization and development of habitat formers. These conditions, along with physical alterations to the river shorelines and persistently unstable substrate conditions demonstrates that the absence of habitat formers in the vicinity of the LEC is not related to the discharge and, even in the absence of the discharge, habitat formers would not be able to colonize the area.

13. Magnitude and duration of any identifiable thermal effects

The retrospective and predictive assessments show that there are no discernable effects related to the LEC thermal discharge outside of the Discharge zone which is within the allowable mixing zone. At the most upstream end of the Thermally Exposed zone, temperatures within the thermal plume are, at most, 6°F above ambient. In addition, the thermal discharge is typically less than 5 percent of the Missouri River flow and the duration of any exposures are usually brief, transiting through the upper portion of the thermal plume within an hour and a half.

14. Sublethal or indirect effects

The predictive assessment shows all RIS may experience slightly earlier spawning and increased growth rates under the worst-case conditions associated with the LEC thermal discharge. Little to no difference in spawning or growth rates are expected under typical plant operating conditions. These results demonstrate that no adverse effects on reproduction or growth are associated with the LEC thermal discharge.

15. No thermal effects on rare or unique habitats

There are no habitats in the Thermally Exposed or Downstream zones designated as "unique or rare" for this portion of the LMOR.

16. Presence of critical function zones within thermally exposed areas

There are no critical function zones (e.g., critical spawning and nursery areas) present within the Thermally Exposed and Downstream zones for any of the RIS. The predictive assessment also showed that there would only be minor episodic exclusion from a small area of habitat within the Thermally Exposed zone and only under worst-case exposures.

17. Trends in the aquatic community

The retrospective analysis shows the aquatic community was similar over time and between the Upstream Reference and Thermally Exposed zones based on diversity and assemblage composition metrics. A standardized difference test combining the results of multiple community metrics showed that the differences between the zones was inconsequential and demonstrated no appreciable harm to the aquatic community.

18. Interaction of the thermal discharge with other pollutants

In the LMOR, there are no other sources of thermal discharges anywhere near the LEC such that there is no potential for additive or synergistic effects of the LEC's thermal discharges with any other thermal discharges.

The areas of the LMOR exposed to elevated temperatures is relatively small and the water passes through these exposed areas rapidly (< 2 hours). Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of algal growth, the rate of contaminant uptake, the rate of bacteria growth, or the rate of oxygen consumption and result in greater adverse impacts to the LMOR.

Overall, the results of this analysis demonstrate that the LEC's thermal discharge will not exacerbate existing environmental issues in the LMOR through additive or synergistic effects of the heat discharged combined with other existing thermal or other pollutants.

Overall Conclusions

Together the results of the screening analysis and the retrospective and predictive assessments demonstrate that no appreciable harm has or will occur to the BIC in the LMOR as a result of the LEC thermal discharge. The results of the screening analysis and the retrospective and predictive assessments were evaluated with respect to 18 decision criteria identified by the USEPA as indicators of appreciable harm. In each case the available data and analyses demonstrate that the decision criteria were satisfied indicating that no prior appreciable harm has occurred as a result of the LEC's ongoing thermal discharge and the requested alternative temperature limitations (§ 316(a) variance) will assure the protection and propagation of the BIC in the LMOR.

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LIST OF ABBREVIATIONS AND ACRONYMS

ATEL	Alternate Thermal Effluent Limitation
BIC	Balanced Indigenous Community
BIP	Balanced Indigenous Population
BSF	Benthic Fishes Study
BTU/hr	British Thermal Units per hour
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CPUE	Catch per Unit Effort
CSR	Code of State Regulations
CTM	Critical Thermal Maximum
CWA	Clean Water Act
CWIS	Cooling Water Intake System
CXLD	Channel Cross-Over L-Dike
EAV	Emergent Aquatic Vegetation
EEH	Equitable Environmental Health
EPT	Ephemeroptera, Plecoptera, Trichoptera
FL	Fork Length
FPS	Feet per second
GPM	Gallons per Minute
H-D	Hester-Dendy
km	Kilometers
LEC	Labadie Energy Center
LILT	Lower Incipient Lethal Temperatures
LMOR	Lower Missouri River
LPI	Low Potential Impact
MDNR	Missouri Department of Natural Resources
mg/l	Milligrams per liter

mm	Millimeters
MMR	Middle Mississippi River
MISO	Midwest independent system operator incorporated
MW	Megawatts
$MWQS_t$	Missouri Water Quality Standards
NPAH	No Prior Appreciable Harm
NPDES	National Pollution Discharge Elimination System
OLD	Outside Bend L-Dike
PCB	Polychlorinated biphenyls
RIS	Representative Important Species
RM	River Mile
SAV	Submerged Aquatic Vegetation
T&E	Threatened and Endangered
TDP	Thermal Discharge Parameter
TL	Total Length
UEC	Union Electric Company
UILT	Upper Incipient Lethal Temperature
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Wood	Wood Environment and Infrastructure, Inc.
ZID	Zone of Initial Dilution

1. INTRODUCTION

Ameren Missouri's (Ameren) Labadie Energy Center (LEC) is a steam electric power plant located in Labadie, Missouri on the south bank of the lower Missouri River (LMOR) near River Mile (RM) 57 in Franklin County, 35 miles west of St. Louis, Missouri (Figure 1-1). The LEC has four generating units, each with two circulating water pumps, and a gross generating capacity of 2,580 megawatts (MW). The LEC utilizes once-through cooling and withdraws water for each unit from the Missouri River via a shoreline intake structure (Figure 1-2). The resulting heated effluent is discharged to a 1,400-foot-long artificial discharge canal and the adjacent navigation channel of the LMOR (Figure 1-2). This discharge of heat is regulated through a National Pollutant Discharge Elimination System (NPDES) permit (MO-0004812) issued by the Missouri Department of Natural Rsources (MDNR).

1.1 LABADIE THERMAL REGULATORY HISTORY

For much of its operating life, the LEC has operated pursuant to variances duly authorized and issued under § 316(a) of the Clean Water Act. Biological studies and hydrothermal modeling were first performed in the mid-1970s as part of the facility's initial NPDES permit application. Those studies concluded that the LEC was a site of low potential impact for all biotic categories (EEH 1976; UEC 1976). An NPDES permit was issued in 1977 which included an approved alternate effluent limitation (§ 316(a) variance). Thereafter, MDNR renewed the § 316(a) variance over several permitting cycles until 2015. Although limited biological studies were periodically conducted, a complete new demonstration study was not performed. In issuing a renewed NPDES permit in 2015, MDNR noted a need for updated biological studies and established an interim thermal limitation substantively equalivent to the prior variance limitation. The MDNR also imposed a water-quality based final thermal effluent limitations and required Ameren to reestablish a biological monitoring program in accordance with 40 Code of Federal Regulations (CFR) 125 Subpart H. Specifically, in Section D.2.h, of the 2015 NPDES permit required:

> *Six months prior to permit expiration, the permittee shall submit a report detailing how the results of the monitoring program and the recommended path forward to achieve compliance. If a recommendation of the report is reissuance of the 316(a) variance, then a request for reissuance of the 316(a) variance must be submitted detailing how the monitoring program supports the requirements of no appreciable harm, specifically:*
>
> 1. *That no appreciable harm has resulted from the normal component of the discharge taking into account the interaction of such thermal component with other pollutants and the additive effect of other thermal sources to a balanced, indigenous community of shellfish and fish and wildlife in and on the body of water into which the discharge has been made; or*
> 2. *If applicable, that dispite the occurrence of such previous harm, the desired alternative effluent limitations (or appropriate modifications thereof) will nevertheless assure the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife in and on the body of water into which the discharge is made.*

In 2016, Ameren requested a modifcation to the LEC NPDES permit to allow use of a site-specific model to determine compliance with Missouri Water Quality Standards ($MWQS_t$) using a combination of river flow, river temperature, effluent flow, and effluent temperature. The model established that an effluent limitation of 0.95 for the Thermal Discharge Parameter (TDP) value would ensure compliance with the $MWQS_t$. On May 3, 2017, MDNR issued a modified NPDES permit for the LEC establishing a thermal effluent limitation of 0.95 for the TDP for both the interim (through July 31, 2020) and final (effective August 1, 2020) thermal effluent limtations, however allowing the prior interim thermal effluent limitation of 11.16 x 10^9 British Thremal Units per hour (BTU/hr) whenever the river temperature exceeded 87F or if the river flow was less than or eqaul to 24,000 cubic feet per second (cfs).

Via request of Ameren on June 29, 2018 and reply by MDNR on July 11, 2018, the interim thermal effluent limitations in the 2017 permit were terminated, and the final thermal effluent limitations of the permit became effective on August 1, 2018. A subsequent modified permit was issued September 1, 2018, but made no changes to the above permit terms and conditions.

1.2 LABADIE ENERGY CENTER § 316(a) VARIANCE REQUEST

Retrospective application of the site-specific TDP model adopted in the 2017 NPDES permit to the LEC flow and thermal discharge records from 2002 through 2018 shows that the LEC thermal discharge would have had a TDP < 0.95 approximately 99 percent of the time. Therefore, the potential for exceedance of a TDP of 0.95 exists in rare instances when the ambient river temperatures are extraordinarily high, and/or the river flow is extraordinarily low (Kleinfelder 2016).

Section 316(a) of the Clean Water Act (CWA) and the $MWQS_t$ allow a thermal discharger to seek alternative thermal effluent limitations (ATEL) [§ 316(a) variance] through demonstration that the less stringent alternate effluent limitations would be protective of aquatic life in the receiving waterbody as a whole. Ameren is requesting such a variance from the $MWQS_t$ under § 316(a) to account for those limited instances when there is a potential for exceedance of the water quality standards for temperature. Ameren is proposing the following alternative temperature effluent limit to ensure continued operation of the LEC while, at the same time, assuring the protection and propagation of a balanced indigenous community in the LMOR:

- A TDP of greater than 0.95 will be allowed under conditions when the river flow is less than 40,000 cfs or ambient river temperatures are greater than 87°F;
- A TDP of greater than 0.95 will be allowed in no more than 6 percent of the days in any calendar year; and
- On any day where the TDP is greater than 0.95, the mixing zone must be less than 40 percent of the volume of the river as calculated by the equations in the permit.

1.3 PURPOSE OF THIS REPORT

This Labadie Energy Center § 316(a) Final Demonstration (Demonstration) has been prepared to address requirement D.3.b of the LEC's NPDES permit issued by the MDNR on May 3, 2017. More specifically, this Demonstration evaluates whether the LEC past and current operation, which included rare instances when a TDP value of greater than 0.95 would have occurred, has resulted in appreciable harm to the aquatic biota in the LMOR near the LEC. In addition, this Demonstation asseses whether the proposed alternative effluent limits for temperature will assure the protection and propagation of the balanced indigenous community of the LMOR.

1.4 REPORT ORGANIZATION

Section 2 of this Demonstration briefly describes the LEC discharge and the characteristics of the Missouri River in the vicinity of the LEC. It also provides an overview of the applicable $MWQS_t$ and mixing zone criteria and a description of the LEC permit limits and thermal plume. Section 3 provides an overview of § 316(a) of the CWA and relevant concepts that will be addressed later in the Demonstration. Section 4 presents the biotic category rationales including a brief characterization of each biotic community in the vicinity of the LEC and the applicable "area of low potential impact" decision criteria from the 1977 draft United States Environmental Protection Agency (USEPA) Guidance Manual (Guidance Manual). Section 5 presents the retrospective assessment to address the “no prior appreciable harm” (NPAH) decision criteria for the fish and benthic macroinvertebrate biotic categories. Section 6 presents the predictive assessment to evaluate whether the balanced indigenous population will be protected and maintained in the event the TDP limit is exceeded. The master rationale in Section 7 summarizes the conclusions for each biotic category and whether the no prior appreciable harm criteria have been met. Finally, Section 8 provides a list of references used in preparing this Demonstration. Supporting appendices to this report are provided under separate cover.

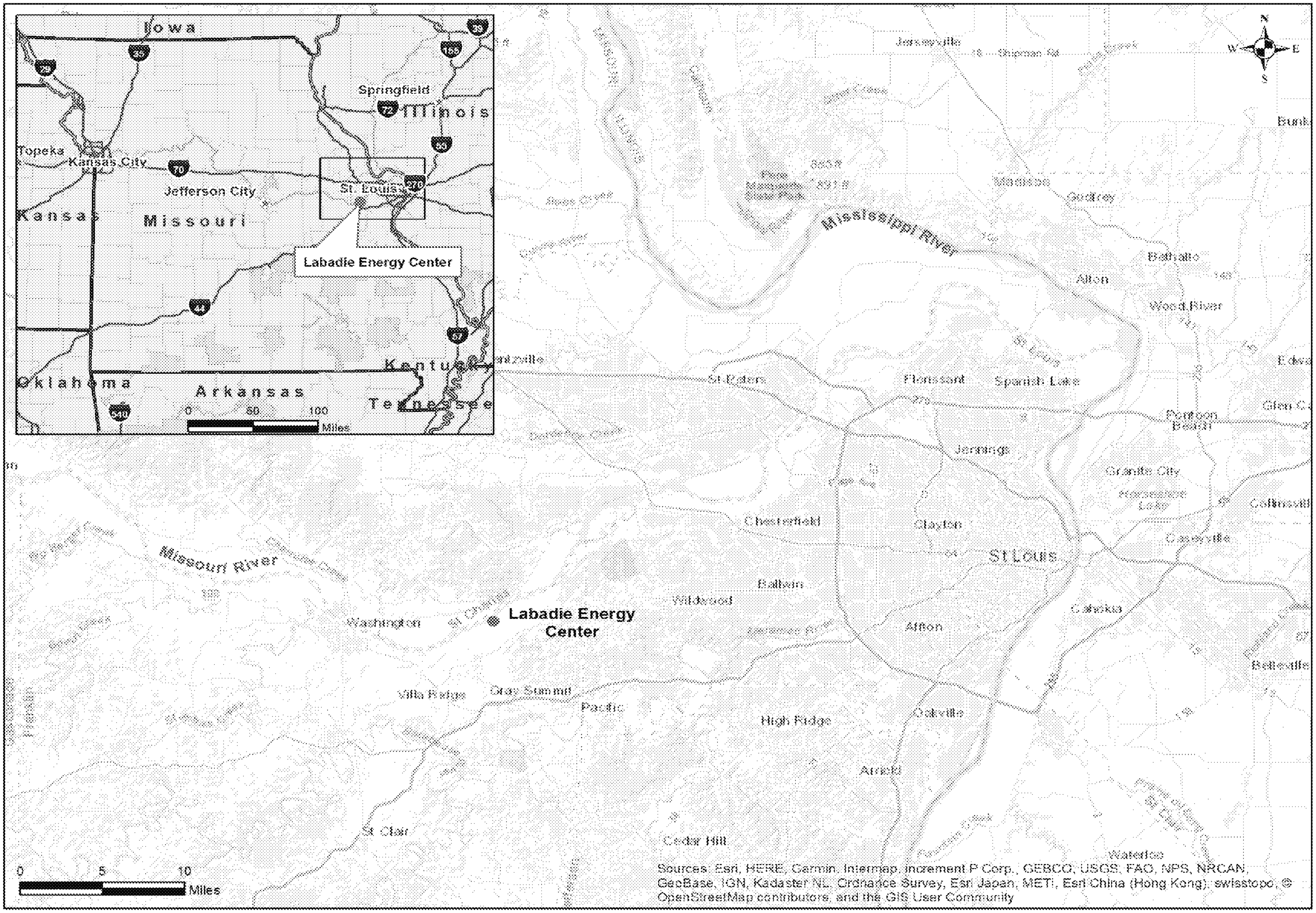


Figure 1-1 General geographical location of the LEC.

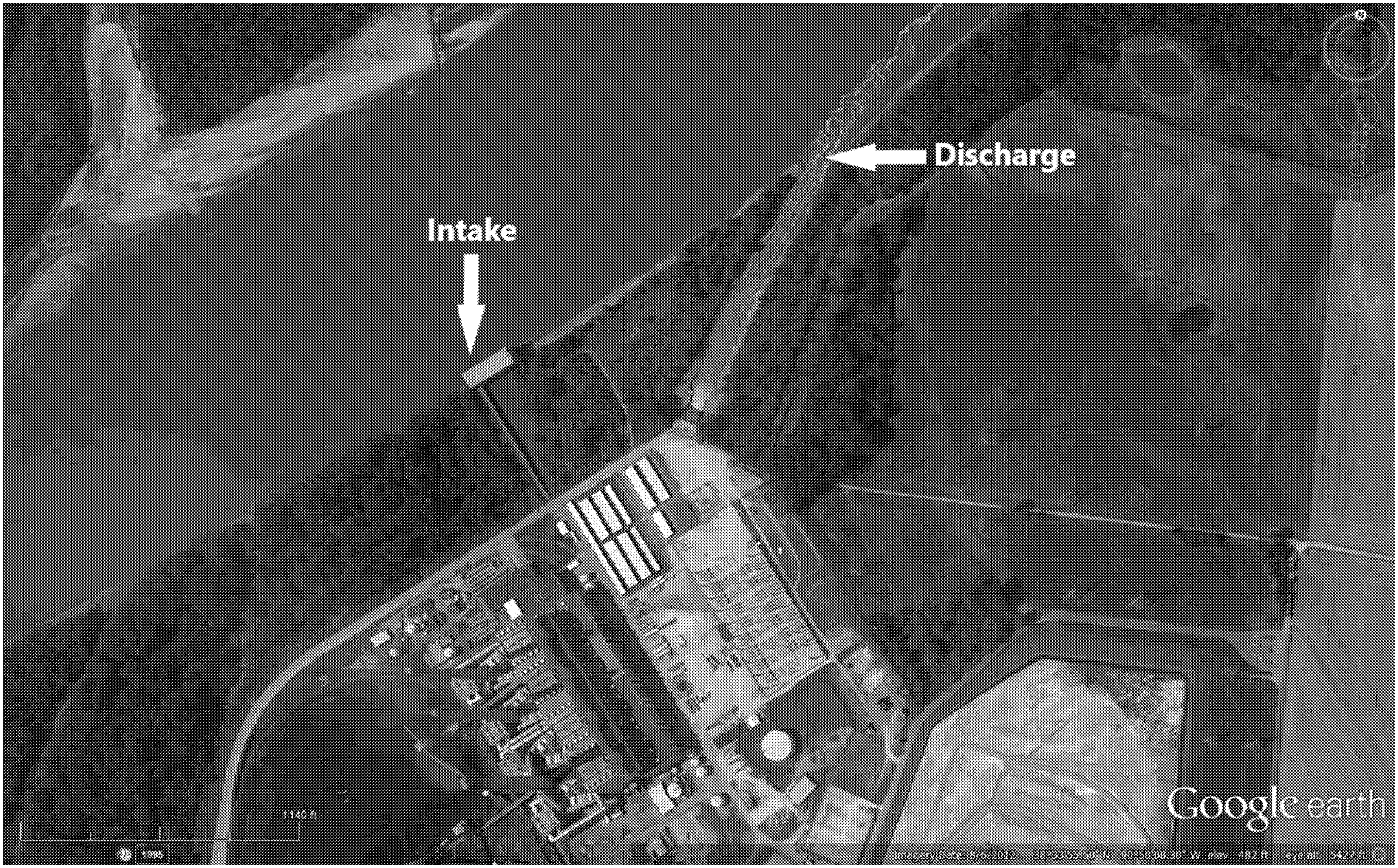


Figure 1-2 Aerial photograph of the LEC showing the cooling water intake and artificial discharge canal.

(Source: Google Earth)

2. LABADIE AND THE ADJACENT MISSOURI RIVER

2.1 CHARACTERISTICS OF THE MISSOURI RIVER IN VICINITY OF LABADIE

The Missouri River is one of the major river systems in the United States, with a 529,350 square mile drainage basin. It flows 2,341 miles from its headwaters at the confluence of the Gallatin, Madison, and Jefferson Rivers near Three Forks, Montana to its confluence with the Mississippi River at St. Louis, Missouri. The Missouri River flows from the Northern Rocky Mountain physiographic province through the glaciated Great Plains and Central Lowlands provinces, and finally through the unglaciated, limestone-dolomite Ozark Plateaus (Galat et al. 2005a, 2005b). Approximately 70 percent of the Missouri River Basin lies within the semi-arid Great Plains, so it is largely a dry-land river.

The geomorphology of the river originally was the product of highly variable daily and seasonal flow rates that carried sediments from the highly erodible soils typical of the Missouri River Basin. The result was a complex, meandering river basin and flood plain that was continually shifting but nevertheless in dynamic equilibrium. The presettlement Missouri River had a wide, highly braided channel with many unconnected islands and was characterized by highly turbid waters, wide fluctuations in temperature (and flow as noted above), and an unstable sand-silt substrate (Pflieger and Grace 1987).

The LMOR has been altered in both its channel form and flow regime by channelization and upstream dams (Johnson et al. 2006). Channel modifications in the LMOR began in the early 1800s with clearing and snagging to improve conditions for steamboat navigation (Chittenden 1903) followed by a focus on channel deepening and bank stabilization efforts (Pflieger and Grace 1987). River modifications have resulted in an estimated loss of up to 50 percent of the original water surface area from Rulo, Nebraska to the mouth (Funk and Robinson 1974). In addition, many of the features that provided habitat diversity to the river were lost.

Flow regulation began on the Missouri River in the late 1930s and was completed with the closure of the Missouri River Reservoir System in 1954 (Ferrell 1993; Galat and Lipkin 2000; Jacobson and Heuser 2001). The system is managed for multiple purposes, including maintenance of commercial navigation flows, flood control, hydropower, public water supply, recreation, and fish and wildlife resources. The U.S. Army Corps of Engineers (USACE) Northwestern Division, Kansas City District, is responsible for maintenance of the federal navigation channel. The USACE Civil Works Division manages 500 miles of the Missouri River, including projects related to habitat restoration and recovery programs, recreation, flood risk management, navigation, riverbed degradation, and dam and levee safety. USACE also reviews and issues permits for commercial dredging operations under the Rivers and Harbors Act and the Clean Water Act to dredge sand and gravel from the Missouri River below Rulo, Nebraska.

Dam construction and channelization along the Missouri River mainstem has fragmented the river into four types of ecological units: a free-flowing reach upstream of the reservoirs, the reservoirs, remnant floodplains between the reservoirs, and a channelized reach below the most downstream reservoir (NRC 2002). The channelized reach, which includes the portion of the river where the LEC is located, extends approximately 735 miles to St. Louis, or about one-third of the total length of the Missouri River. Upstream modifications have reduced or eliminated the river's natural flow regime in which flood pulses in the spring and early summer would create new and productive habitats, cycle organic material and nutrients between the channel and floodplain, replenish water in the floodplain, and serve as cues for spawning of fish and other organisms (USFWS 2003). As a result, the amount of productive, natural habitat has been greatly reduced throughout the system.

The current channel morphology in the LMOR is dominated by rock wing dikes and revetments constructed as part of the Missouri River Bank Stabilization and Navigation Project (Ferrell 1996). These structures stabilized the banks and narrowed and focused the river geometry to help maintain the navigation channel from St. Louis, Missouri to approximately 750 miles upstream at Sioux City, Iowa. The rock structures and revetments (outside of bends) and dikes (inside of bends) force the river into a channel alignment that is self-maintaining.

The typical annual flow cycle in the upstream regulated Missouri River involves peak reservoir storage in July, followed by a gradual decline in storage until late winter (USACE 2006). Flow releases to the LMOR are adjusted according to short-term and annual rainfall amounts and resulting water storage, as well as nesting requirements for the two federally listed bird species (least tern and piping plover) on the storage reservoirs. Targeted flow releases are increased during the navigation period, which normally begins by April 1 near St. Louis and extends until early December. River flow in the LMOR is further supplemented and modulated by tributary inflow.

The Kansas City and Omaha Districts of the USACE, in cooperation with the U.S. Fish and Wildlife Service (USFWS), developed a Draft Missouri River Recovery Management Plan (MRRP) and Draft Environmental Impact Statement (EIS; USACE 2014). The MRRP is an effort to replace lost habitat and avoid a finding of jeopardy to T&E species resulting from USACE projects on the Missouri River related to operation of the mainstem river reservoir system, ongoing navigation, and bank stabilization. Some of the restoration aspects of the program include development of emergent sandbar habitat, shallow water habitat, and wetland and terrestrial habitat. The program also includes ongoing data collection and monitoring to determine if these actions are effective. These actions are being taken pursuant to the 2000 Biological Opinion, amended in 2003 (USFWS 2003).

The changes in flow regimes and destruction of aquatic habitats have greatly influenced the abundance of native species and affected the overall composition of the fish community. Many native fish species are now rare, uncommon, or decreasing in abundance across part or all of their previous range due to the changing ecosystem and habitat losses during recent decades (NRC 2002). Lost also are the flood pulses in the spring and early summer that influenced the river morphology, connected side channels and backwaters to the main channel, created new and productive habitats, cycled organic material and nutrients between the channel and floodplain, replenished water in the floodplain, and served as cues for spawning of fish and other organisms. Productive side channels, chutes, sand bars, islands and backwaters are much reduced. These reductions in ecosystem integrity associated with lost or altered habitat (Hesse and Sheets 1993) likely have contributed to the decline of several native Missouri River fishes, including the federally endangered pallid sturgeon (*Scaphirhynchus albus*) (Dryer and Sandvol 1993). Many of these native fish species are now rare, uncommon, or decreasing in abundance across part or all of their previous range (NRC 2002). In many river reaches, the abundance of non-native species such as Asian carp has become greater than that of native species because of their greater tolerance for the altered temperature regime, flow, turbidity, and habitats.

The presettlement fish community in the Missouri River was characterized by relatively few species adapted to the high turbidity and unstable environment (wide fluctuations in flow, temperature, and shifting substrate) of the river such as the pallid sturgeon, flathead chub, western silvery minnow, plains minnow, and sicklefin chub (Pflieger and Grace 1987). Pflieger and Grace (1987) examined fish survey data collected at approximately 20-year intervals starting around 1940 through the 1980s and noted an increase in the number of species and substantial changes in relative abundance over time. Changes in the river described above led to decreased turbidity and changes in the type and availability of habitat favoring largely pelagic planktivores and sight feeding piscivores such as gizzard shad, skipjack herring, shiners, and sunfish (Funk and Robinson 1974; Pflieger and Grace 1987). Dominant large fish in surveys from the 1940s included common carp, river carpsucker, channel catfish, and gizzard shad representing 34.9, 18.4, 9.1, and 8.8 percent of the catch, respectively (Pflieger and Grace 1987). Gizzard shad and channel catfish relative abundance increased to 31.8 and 30.8 percent of the catch in the 1980s surveys (respectively), while common carp and river carpsucker declined to represent only 5.9 and 4.8 percent of the catch (respectively) during the same period. In the 1940s surveys small fishes were dominated by plains minnow and flathead chub accounting for 56 and 31 percent of the catch of small fish, respectively (Pflieger and Grace 1987). While plains minnow were still one of the most abundant species during the 1980s surveys, their relative abundance decreased to 36 percent of the catch from 56 percent during the 1940s surveys. Emerald shiner was the second most abundant species in the 1980s surveys representing 28.5 percent of the catch, up from 0.1 percent in the 1940s surveys. The relative abundance of flathead chub decreased markedly to represent only 1.1 percent of the catch during the 1980s surveys. Funk and Robinson (1974) noted a decrease of almost 80 percent in commercial catch, primarily comprised of carp, buffaloes, and catfishes, from 1945 to 1963. They attributed this trend to reduction and deterioration of the Missouri River fish habitat as a result of the navigation and stabilization project.

Pflieger and Grace (1987) noted several factors contributing to the maintenance and increases in the populations of different species within the Missouri River in addition to the changes in flow and habitat. These include escapement from reservoirs (e.g., white bass, bluegill, freshwater drum, emerald shiner, river shiner, and rainbow smelt), accidental and intentional introductions (e.g., rainbow smelt, white bass, and grass carp), and stragglers from tributaries (e.g., spotted bass, longear sunfish, and Ozark minnow). They also postulated that the decrease in common carp between the 1940s to the 1980s surveys resulted from an improvement in water quality. While Pflieger and Grace (1987) suggested that the increase and upriver range expansion of threadfin shad in the Mississippi River may be a result of thermal discharges from power plants, they could not definitely ascribe any changes in the Missouri River fish fauna to thermal discharges. At the time of their paper, Pflieger and Grace (1987) suggested that if the public works projects responsible for the changes in the Missouri River were complete, fish populations would continue to fluctuate but ultimately reach equilibrium. The also postulated that populations of grass, silver, and bighead carp, would likely continue to increase and become well-established in the Missouri River. As has been well-documented, Asian carp have indeed proliferated in the Missouri River and have become a large part of the fish community.

The LEC is located on the south bank (right descending bank) in the channelized reach of the LMOR (Figure 2-1) in an area known as Labadie Bottoms. The Missouri River is approximately 1,300 feet wide and has an approximate average depth in the range of 16 feet in the vicinity of the LEC cooling water intake structure (CWIS) and discharge canal (Kleinfelder 2016). However, depth sounding surveys from 2001 to 2014 in the vicinity of the LEC indicated that the shape of the river bottom changes somewhat with time. Along the lower Missouri River there are numerous wing-, pole-, and L-shaped dikes and shoreline revetment areas, such as downstream of the LEC discharge canal, that have been constructed along the shoreline to improve and maintain the navigability of the river (Figure 2-1). The river depth in the vicinity of the LEC increases sharply because the channel closely approaches the south bank in this area. Sandy beaches are exposed at low water levels. The river currents past the plant are swift, with typical velocities estimated between 2.6 and 4.8 feet per second (fps). Rooted vegetation within the river is lacking and the substrate consists of rock, stone or gravel in areas of current, and silt or clay in depositional areas.

Aquatic habitats in the vicinity of the LEC have also been substantially altered over time by the construction of revetments and dikes and by dredging to maintain a 300-foot wide navigation channel that is at least 9 feet deep. As a result, the channel now is narrower and more uniform than its previous form, with a trapezoidal cross-section resulting in steeper embankments and faster currents. River meanders have been straightened, natural riparian vegetation has been diminished, variations in river flows and water temperatures are reduced, periodic overbank flow to the floodplain and its nutrient cycling benefits have been eliminated or reduced, sediment transport processes have been altered, and natural processes of cut and fill alleviation have been modified (NRC 2002). In a 32-mile reach of the LMOR from RM 36 to 68 which includes the area where the LEC is located, changes to the river have resulted in the loss of 56 percent of the water surface area between 1879 and 1972 along with a 98 percent reduction in unconnected islands and a 12 percent reduction in channel area from 1879 to 1954 (Funk and Robinson 1974).

In the vicinity of the LEC, river flow follows a typical seasonal pattern with higher flows in late spring and early summer as a result of higher inflows and regulatory releases (Figure 2-2). In general, there is about a three-fold difference in average flows from the highest to the lowest flow period of the year although changes across the years at any point in time can be considerably larger. Median annual flows in recent years (2002 – 2018) exhibited substantial differences from one year to the next, most likely a result in changes in upstream precipitation (Figure 2-3). Flows in relatively high flow years (2008 – 2011) were two to three times higher than those in relatively low flow years (2002 – 2006 and 2012 – 2013). There was no evidence of any long-term trend in river flows across this 17-year period.

Water temperatures in the LMOR followed a seasonal pattern typical of larger mid-Western rivers ranging from less than 40°F in winter to more than 80°F in summer (Figure 2-4). This pattern was fairly consistent across the years although temperatures as high as 87°F were reported approximately one percent of the time. Differences in annual median water temperatures were relatively small in recent years, ranging from just under 55°F to slightly over 63°F (Figure 2-5).

Dissolved oxygen (DO) concentrations in the LMOR followed a seasonal pattern opposite of that of water temperatures ranging from more than 14 milligrams per liter (mg/l) in winter to less than 5 mg/l in summer (Figure 2-6). DO levels, as measured at the Hermann gage, were less than the MO water quality standard of 5 mg/l approximately 5 percent of the time overall and more than 19 percent of the time in July. These low dissolved oxygen levels have been reported to be a result of excess organic materials from wastewater treatment systems, excess animal waste, excess nutrient loads (fertilizer) and excess sedimentation from stream bank and sheet erosion (MDNR 2015). There was no evidence of a long-term trend in DO levels (Figure 2-7).

The LMOR is also affected by sediment, nutrient, and pesticide runoff from agriculture; sediment and metal loadings from mines; urban stormwater discharges; wastewater and industrial plant discharges; septic system leaching; and entrapment of sediments and pollutants behind dams. (USACE 2016). Inputs from these sources include nutrients, toxic chemicals and bacteria, each of which degrade the quality of the aquatic habitats in the LMOR.

Nutrient inputs, principally from agricultural runoff and sewage treatment plan discharges, result in elevated levels of organic nitrogen, nitrate, total phosphorus, and ortho-phosphorus. As a result, approximately 17 and 29 percent of the Missouri River was categorized as being in a most-disturbed condition for total nitrogen and total phosphorus, respectively, with phosphorus concentrations increasing progressively downriver from the Gavins Point Dam (Angradi et al. 2011).

Further, a variety of organic chemicals including organochlorine pesticides, particularly chlordane, heptachlor, and dieldrin along with polyaromatic hydrocarbon compounds (PAH) in the lower river was detected by sampling the water column at Hermann, MO (Petty et al. 1993). The Missouri Department of Health and Senior Services has issued a fish consumption advisory against consumption of shovelnose sturgeon eggs from the Missouri River due to Polychlorinated biphenyls (PCB) and chlordane contamination, and a consumption limit of one meal per month for shovelnose sturgeon flesh and all buffalo species due to PCB, chlordane, methyl mercury contamination (MDHSS 2018). There is a total ban on consumption of sturgeon roe. There also is a consumption limit of one meal per week for flathead catfish, channel catfish, and blue catfish greater than 17 in. in length and common carp greater than 21 in. from the Missouri River.

Greater than 12 percent of the Missouri River length was determined to have sediments resulting in toxicity to exposed organisms (Angradi et al. 2011) and were concentrated in the Fort Peck Reach and near Kansas City (RM 312-438), or more than 255 RMs upstream of Labadie. Echols et al. (2008), sampling 19 location in the LMOR between Omaha NB and Jefferson City MO, concluded that metal concentrations in the sediments at most of these locations were below probable effects level thresholds (MacDonald et al. 2000), and that they would likely have minimal toxicological effects on biota based on those criteria.

Finally, the lowermost section of the river (St. Charles/St. Lewis Counties), in which the LEC resides, is included in Missouri's § 303(d) 2016 list of impaired waterbodies due to bacteria (*E. coli*), with impaired use for whole body contact recreation (MDNR 2016). This impaired segment was first added to the § 303(d) registry in 2008 and it includes waters that are part of a public water supply.

2.2 LABADIE THERMAL DISCHARGE

The LEC typically operates year-round with only minor seasonal differences as a result of demand changes and maintenance outages (Figure 2-8) and average annual generation has been relatively consistent across the past 17 years (Figure 2-9). Ameren is a member of the Midcontinent Independent System Operator Incorporated (MISO), a regional transmission authority that controls the dispatch of generation assets, including the LEC, within its multi-state regions. MISO operates on a market basis and matches demand and supply on an instantaneous and continuous basis.

The LEC uses water from the LMOR to cool each of its four generating units that is withdrawn through a common shoreline intake structure. Each unit has two circulating water pumps each that are rated at 125,672 gallons per minute (gpm) or 280 cfs at 56 feet of head per pump. At a normal water level of El. 455 feet, the total facility cooling water withdrawal capacity of the LEC is 1,005,378 gpm (2,240 cfs). Except during major outages or intake structure maintenance activities, each unit typically runs both of its two circulating pumps continuously. Hence, there is little seasonal or annual variation in cooling water discharge volumes. The LEC currently does not use chlorination or other biocide applications at its intake.

After water passes through the LEC's steam condensers, the water withdrawn for cooling purposes is discharged back into the river via an open discharge canal that is approximately 1,400 feet long and 100 feet wide. The confluence of the discharge canal with the Missouri River is located approximately 1,500 feet downstream of the intake structure (Figure 1-2). The amount of water discharged is slightly less than the amount withdrawn owing to minor consumptive uses within the facility. Once entering the Missouri River, the heated effluent is dispersed and transported downstream. The temperature of the effluent discharged is dependent on the ambient river water temperature, plant operation, and intake flow.

The LEC's thermal discharge is rapidly and thoroughly mixed throughout the water column and the resulting thermal plume is restricted to the right descending (south) side of the river (Kleinfelder 2016). The downstream distribution of the thermal plume is driven by the river flow, ambient river water temperature, as well as the LEC's discharge temperature and flow.

2.3 APPLICABLE WATER QUALITY STANDARDS AND CRITERIA

$MWQS_t$ for the LMOR in the vicinity of LEC are as follows:

*For warm water habitats beyond the mixing zone water contaminant sources or physical alteration of the water course shall not raise or lower the temperature of a stream by more than five degrees Fahrenheit (5°F) or two and seven-ninths degrees Celsius (2 7/9°C). Water contaminant sources shall not cause or contribute to stream temperature in excess of ninety degrees Fahrenheit (90°F) or thirty-two and two-ninths degrees Celsius (32 2/9°C). However, site-specific ambient temperature data and requirements of sensitive resident aquatic species will be considered, when data are available, to establish alternative maxima or deviations from ambient temperatures. (*10 Code of State Regulations [CSR] 20-7.031).

The size of an allowable thermal mixing zone is defined in Section 10 CSR 20-7.031 (5)(D)6 as:

Thermal mixing zones shall be limited to twenty-five percent (25%) of the cross-sectional area or volume of a river, unless biological surveys performed in response to section 316(a) of the federal Clean Water Act (or equivalent) indicate no significant adverse impact on aquatic life. Thermal plume lengths and widths within rivers, and all plume dimensions within lakes, shall be determined on a case-by-case basis and shall be based on physical and biological surveys when appropriate.

2.4 LABADIE PERMIT LIMITS

The discharge of heat from the LEC is regulated by a NPDES Permit (MO-0004812) last modified by the MDNR on September 1, 2018. This permit incorporates a daily maximum and monthly average TDP limit of 0.95. Equations to calculate the TDP are provided in the permit while the derivation and validation of these equations for the LEC are described in Kleinfelder (2016). The TDP limit incorporates a 5 percent margin of safety to ensure compliance with the $MWQS_t$ at the edge of the allowable mixing zone as described in the previous section.

In addition to this permit limit, Special Condition #20 in the Labadie NPDES permit requires Ameren to implement an approved monitoring plan to characterize the thermal mixing zone throughout the river downstream from the confluence of the discharge canal and the Missouri River during conditions when the river flow is less than 35,000 cfs and/or the ambient river water temperature is greater than 85°F, as measured at the United States Geological Survey (USGS) Labadie Gage Station (#06935550). Results of the monitoring are to be reported to the MDNR and evaluated to determine whether the measured temperatures are in compliance with the $MWQS_t$ for temperature.

2.5 COMPLIANCE WITH THE LEC THERMAL LIMIT

Since modification of the LEC NPDES permit in 2017, the LEC has not exceeded the applicable TDP permit limit. Further, application of these TDP equations to daily river and plant operational conditions extending over the 17-year period, 2002 – 2018, indicate that the LEC would have met a TDP value of 0.95 (value of 0.95 or less) more than 99 percent of the time (Figure 2-10). The infrequent TDP values greater than 0.95 only occur when river discharge was unusually low and/or water temperatures were well above normal. Seasonally, monthly median TDP values appear to be the inverse of river discharge with highest values in winter and lowest values in late spring (Figure 2-11). Across the 17-year period, the predicted infrequent daily TDP values greater than 0.95 were limited to July, August and, in one case, November (Figure 2-11). Annual median TDP values also were generally inverse of river discharge while not a single predicted daily TDP value of greater than 0.95 was calculated in 12 of the 17 years (>70 percent of the years) (Figure 2-12). Incidents where TDP values greater than 0.95 occur were restricted to those years with especially low river discharge and high water temperatures as discussed in Section 2.1.

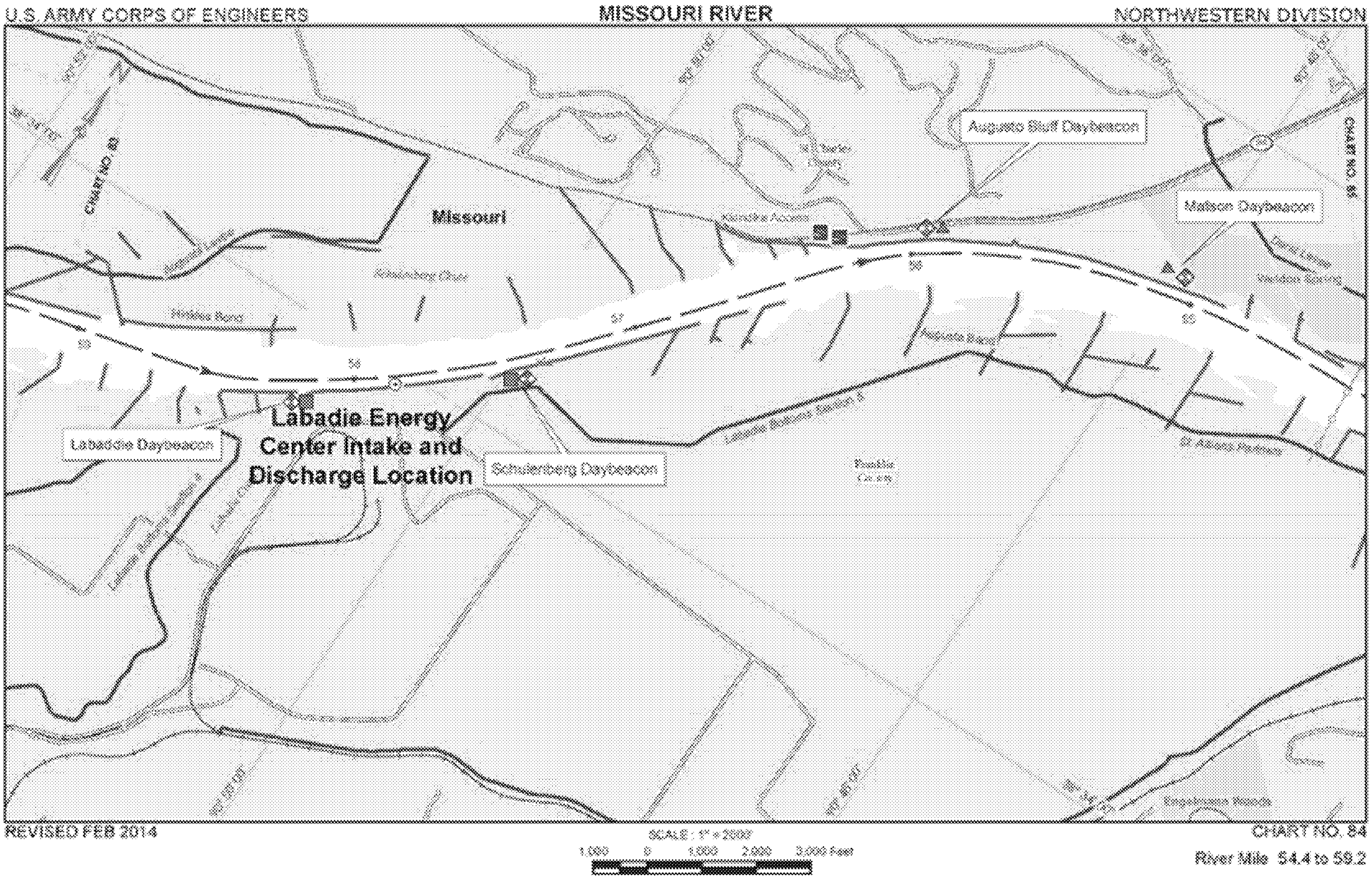


Figure 2-1 United States Army Corps of Engineers navigation chart and levee system near the LEC.

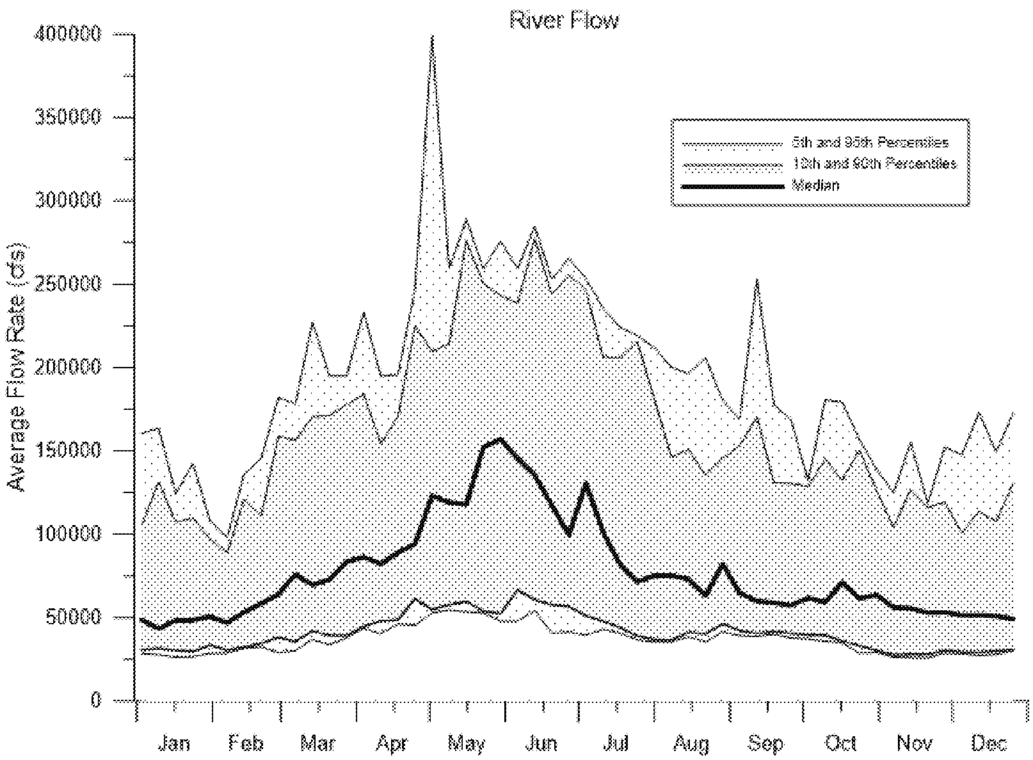


Figure 2-2 Seasonal pattern in river flow in the LMOR as measured at USGS Labadie Gage Station, 2002 - 2018.

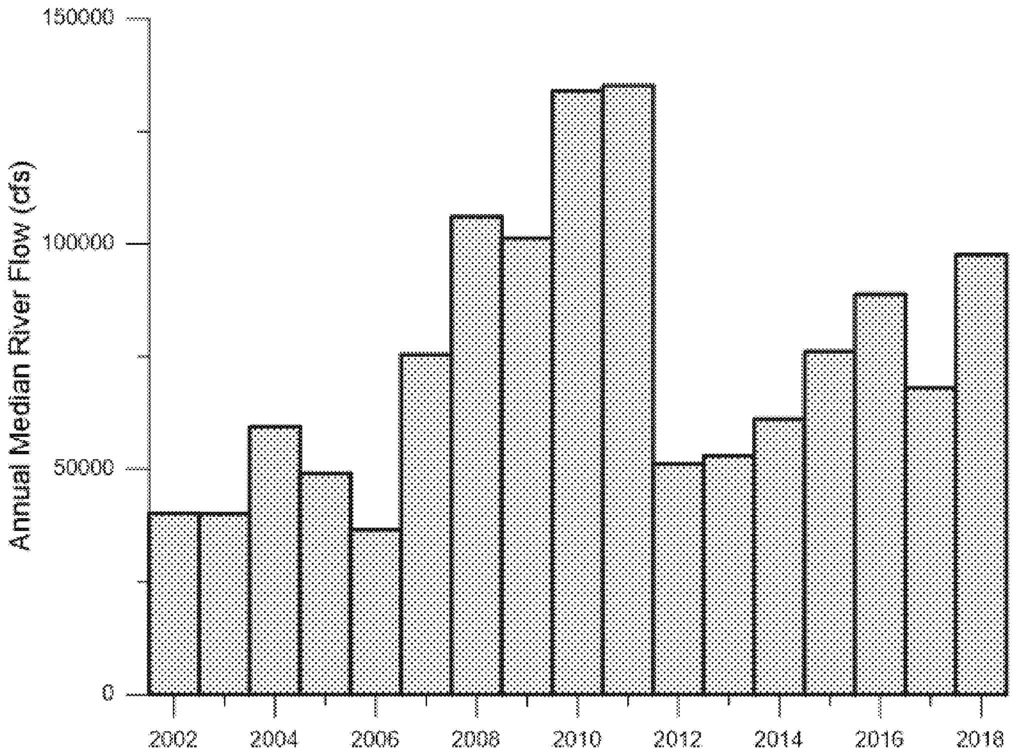


Figure 2-3 Annual median river flow in the LMOR as measured at the USGS Labadie Gage Station, 2002 – 2018.

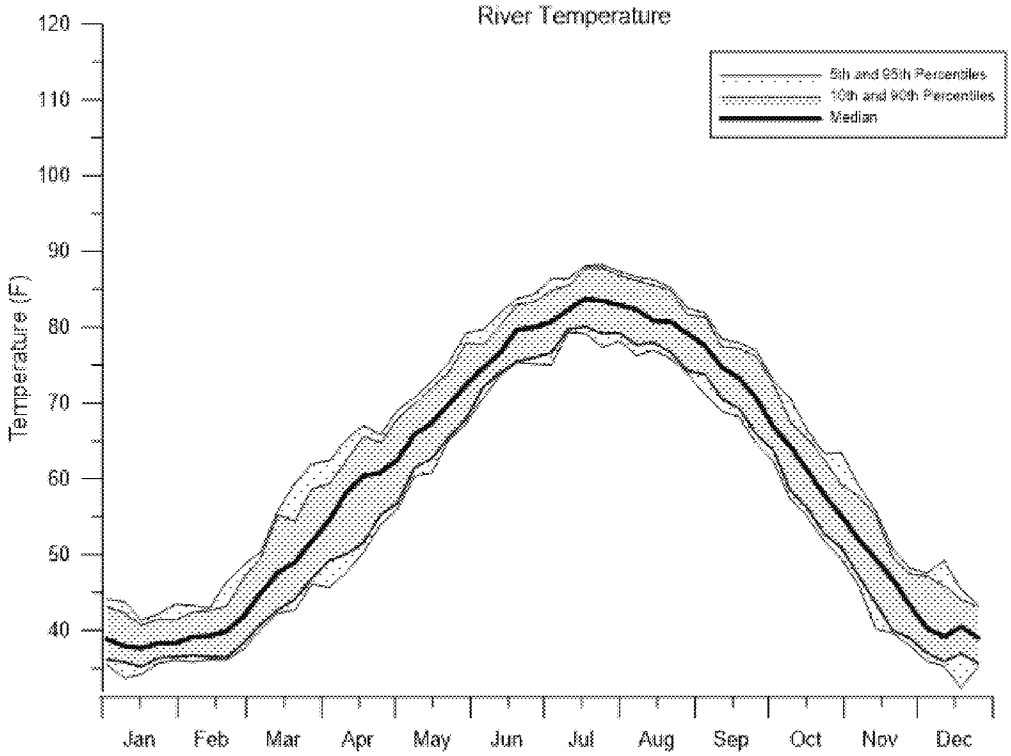


Figure 2-4 Seasonal pattern in river water temperature in the LMOR as measured at LEC intake, 2002 - 2018.

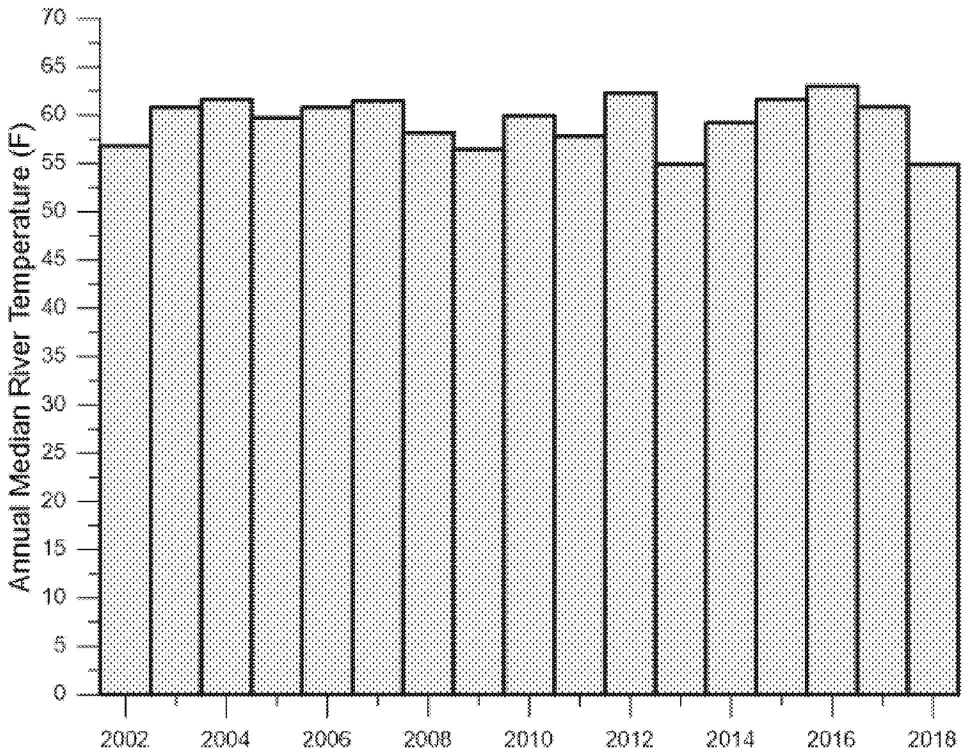


Figure 2-5 Annual median river water temperature in the LMOR as measured at the LEC intake, 2002 - 2018.

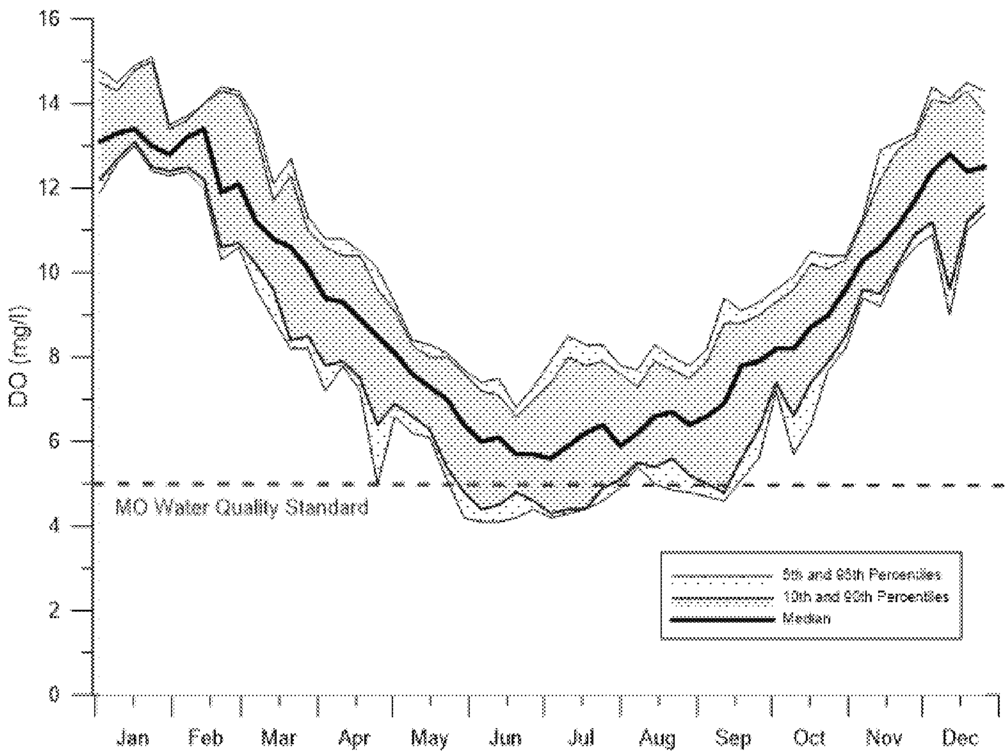


Figure 2-6 Seasonal pattern in river dissolved oxygen in the LMOR as measured at USGS Hermann Gage approximately 40 miles upstream of the LEC, 2007 - 2018.

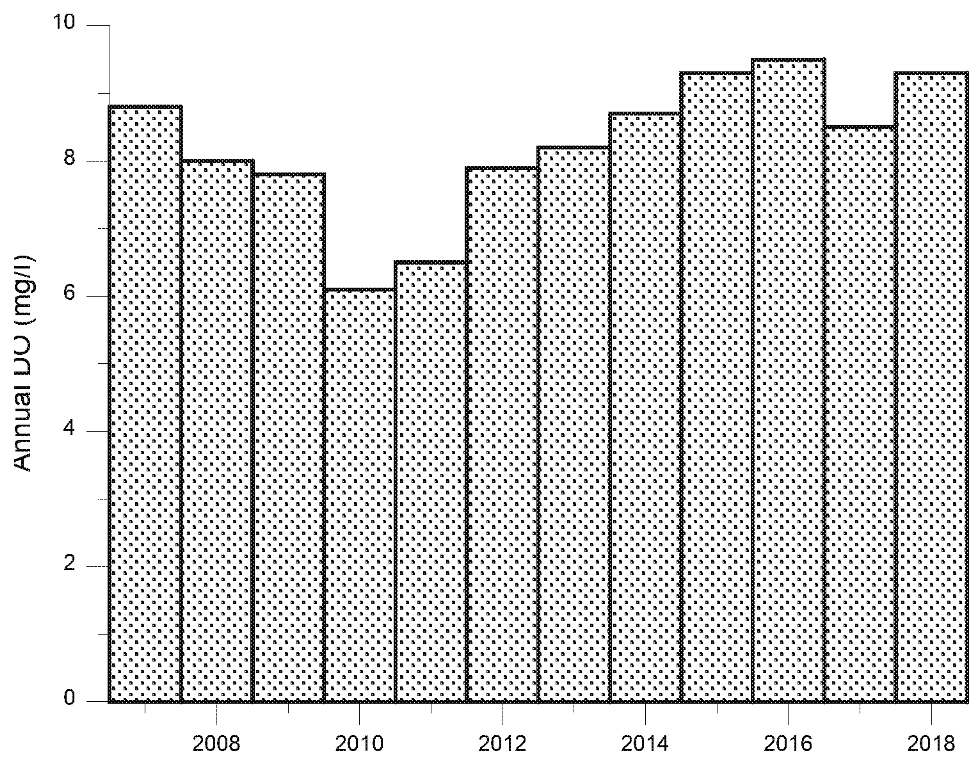


Figure 2-7 Annual trends in river dissolved oxygen in the LMOR as measured at USGS Hermann Gage approximately 40 miles upstream of the LEC, 2007 - 2018.

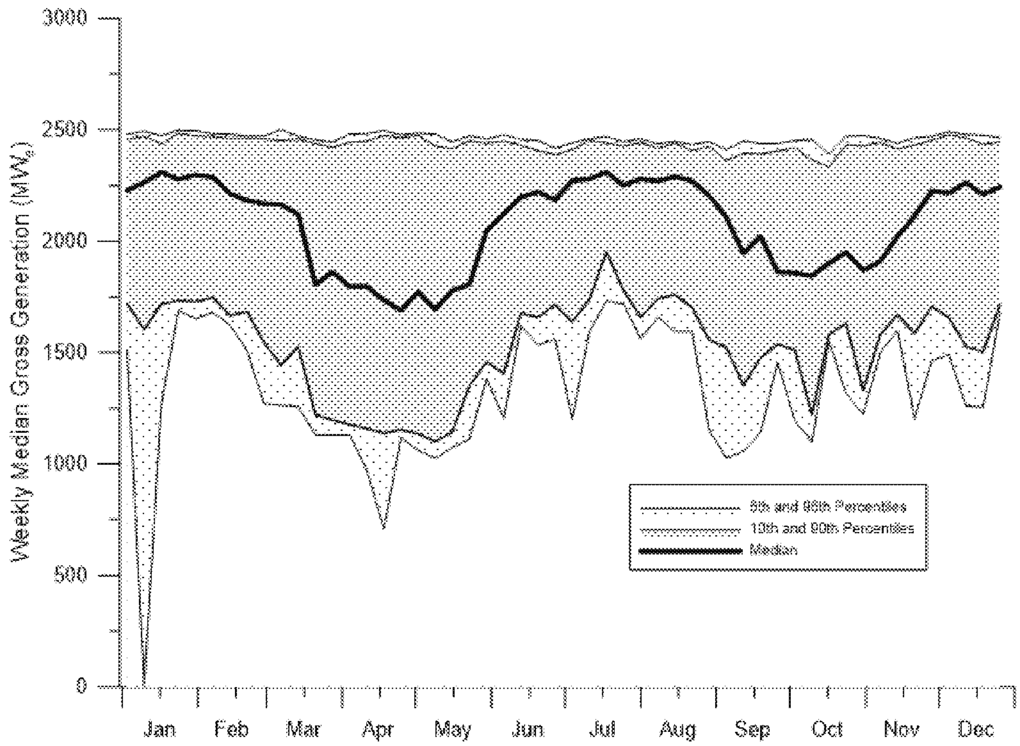


Figure 2-8 Seasonal pattern in gross electrical generation at LEC, 2002 - 2018.

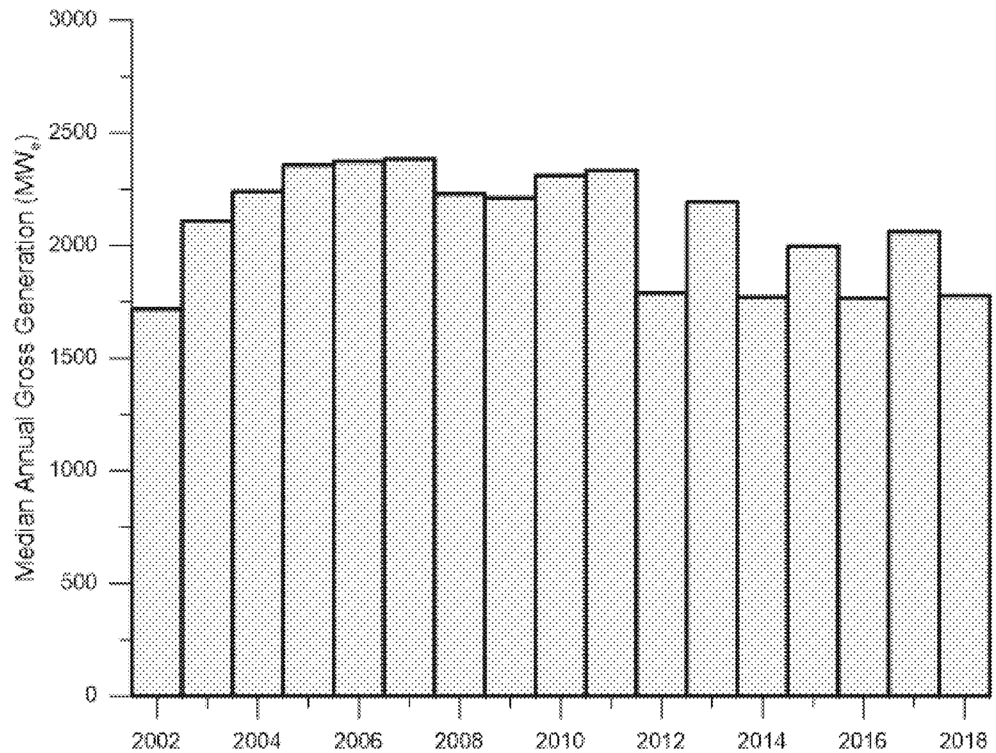


Figure 2-9 Annual median gross electrical generation at LEC, 2002 - 2018.

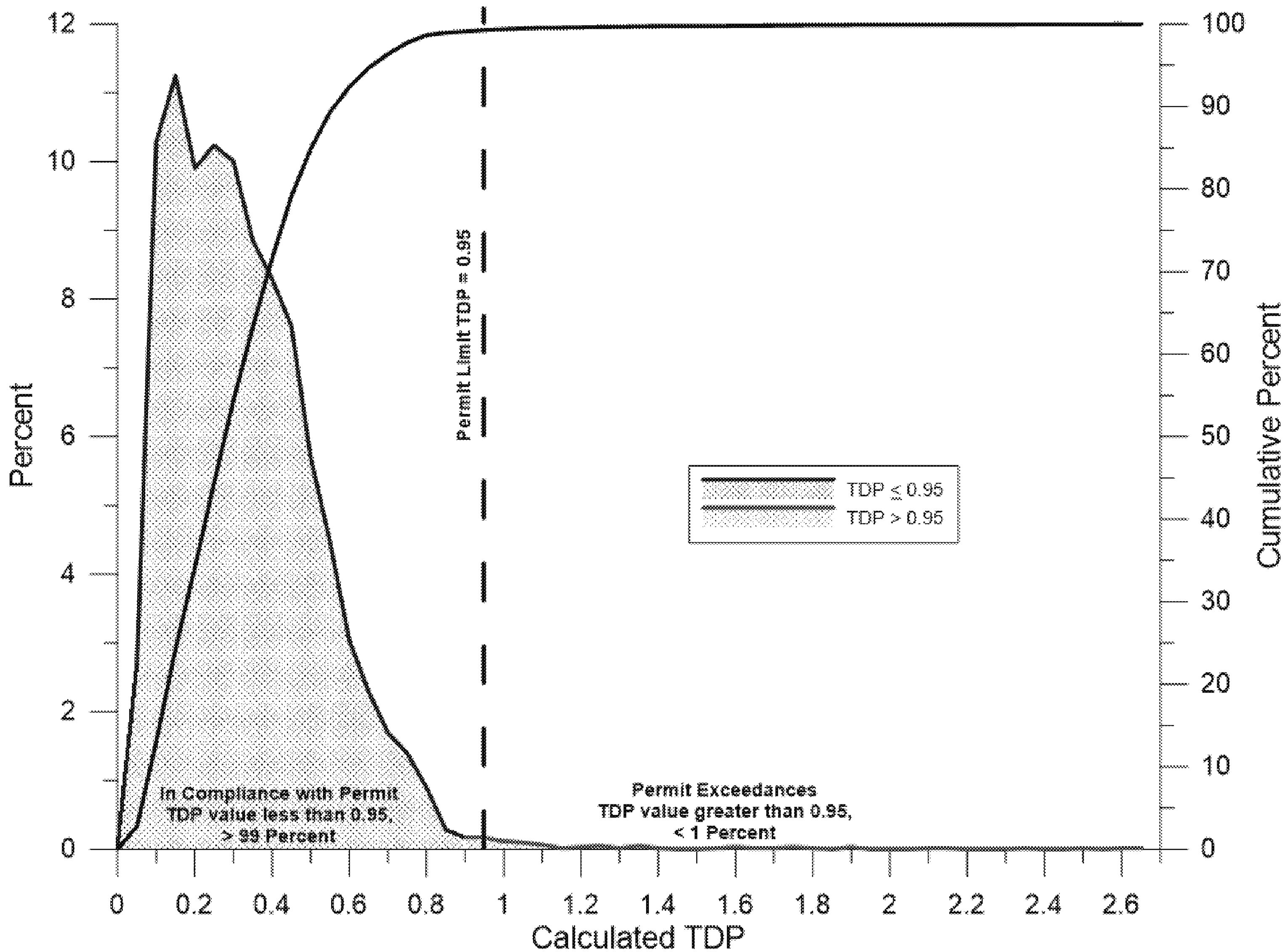


Figure 2-10 Frequency distribution of daily TDP values at LEC over the period 2002 – 2018.

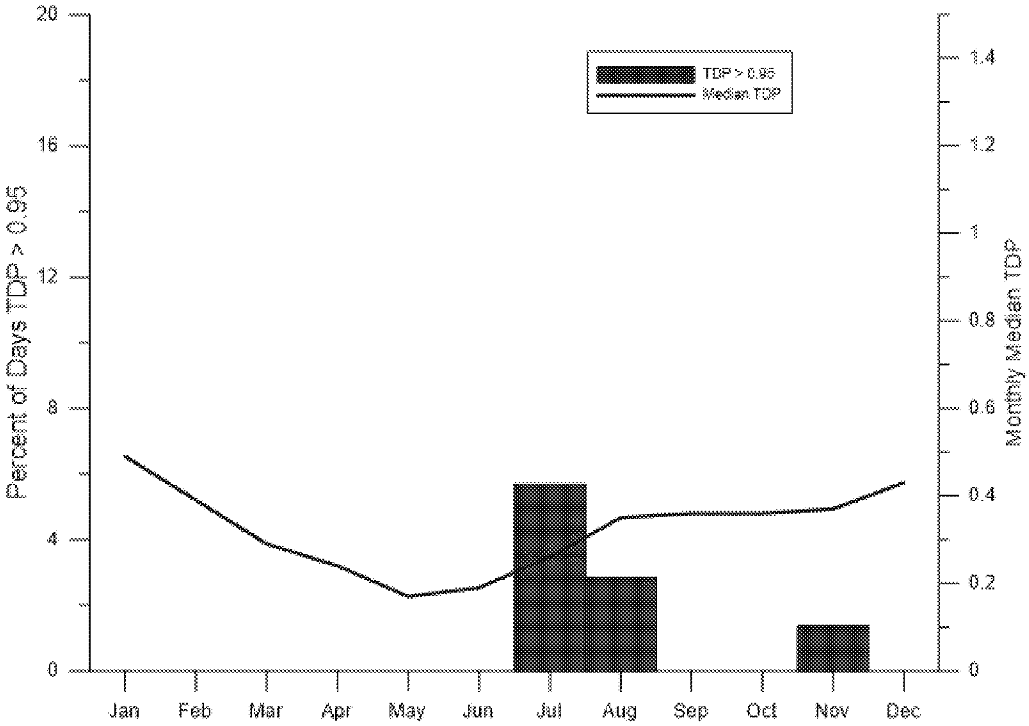


Figure 2-11 Seasonal pattern in TDP values at the LEC from 2002-2018.

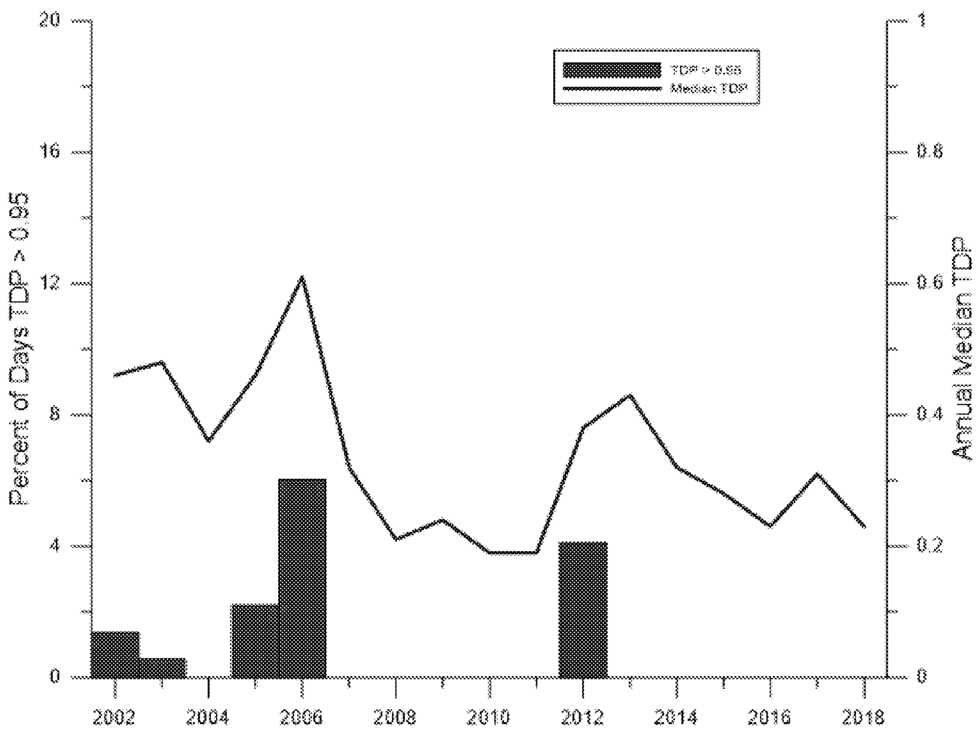


Figure 2-12 Annual trends in TDP values at the LEC from 2002-2018.

3. REGULATORY REQUIREMENTS FOR THERMAL VARIANCE

As demonstrated above, analysis of prior environmental and LEC operational data suggests that there is a potential to exceed the permit thermal limits on a very infrequent basis (< 1 percent of the time). Ameren has evaluated facility operational controls that could reduce that potential even further. However, because the permit thermal limits have the potential to be exceeded, Ameren is requesting a § 316(a) variance for the LEC from the $MWQS_t$ temperature limits that will allow the LEC to continue to operate during periods of discrete yet extreme river conditions.

The MDNR defines a water quality variance as a time-limited designated use and criterion change for a specific pollutant, allowing deviation from meeting a water quality-based effluent limitation for a specific discharger. While MDNR does not provide specific guidance for obtaining a variance from temperature limits, regulations limit the size of the thermal mixing zone to twenty-five percent of the cross-sectional area or volume of a river *"...unless biological studies performed in response to section 316(a) of the federal Clean Water Act (or equivalent) indicate no significant adverse impact on aquatic life. Thermal plume lengths and widths within rivers...shall be determined on a case-by-case basis and shall be based on physical and biological surveys when appropriate."* (10 CSR 20-7.031(5)(D)6).

Hence, it appears clear that MDNR expects requests for thermal variances to be consistent with the requirements of § 316(a) of the Federal CWA.

3.1 OVERVIEW § 316(a) OF THE CLEAN WATER ACT

While the CWA clearly identified heat as a pollutant, Congress recognized that heat is different from other pollutants in that it:

- Is a natural attribute of all waters;
- Can have both positive and negative effects on aquatic life;
- Does not persist or accumulate in the environment but instead rapidly degrades with time;
- Has effects that are transitory; and,
- Can be detected and avoided by many motile aquatic organisms (Bulleit 2004).

It is for all of the above reasons that Congress included § 316(a) in the CWA. This section applies to point sources with thermal discharges and authorizes the NPDES permitting authority (e.g., State NPDES program Director) to impose alternative effluent limitations for the control of the thermal component of a discharge in lieu of the effluent limits that would otherwise be required.

Regulations implementing § 316(a) are codified at 40 CFR Part 125, Subpart H which identifies the criteria and process for determining whether an alternative effluent limitation (i.e., a thermal variance from the otherwise applicable effluent limit) may be included in a permit. Before a thermal variance can be granted however, 40 CFR § 125.72 and § 125.73 require that the permittee "demonstrate" that the otherwise applicable thermal discharge effluent limit is more stringent than necessary to "*assure the protection and propagation of the waterbody's balanced, indigenous population (BIP) of shellfish, fish and wildlife*". Should the permittee be able to demonstrate, with reasonable assurance and based on the best information reasonably available, that a stable, normally functioning BIP will be able to survive and propagate in the receiving waterbody as a whole, then the alternative temperature limits (i.e., variance) should be granted.

3.2 FEDERAL GUIDANCE

USEPA first issued guidance related to implementing CWA § 316(a) in September 1974 (USEPA 1974). This draft guidance was general in nature, focusing more on process and organization of the Demonstration but provided a few key definitions described below. Subsequently in 1977, USEPA released a revised draft CWA § 316(a) guidance entitled "Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements" (Guidance Manual). While neither guidance document was ever finalized, this guidance provides valuable technical information on conducting § 316(a) demonstrations, useful to both facilities and permitting authorities.

USEPA imposes specific expectations for granting or renewing a CWA section § 316(a) thermal discharge variance. The burden of proof is on the applicant (permittee) to demonstrate that it is eligible to receive an alternative thermal effluent limit under § 316(a). To do so requires that the permittee demonstrate to the permitting authority that a thermal effluent limit necessary to meet the requirements of § 301 or § 306 of the CWA is more stringent than necessary to assure the protection and propagation of a BIP in and on the body of water into which the discharge is made. (40 CFR § 125.73(a)).

To secure an alternative thermal discharge limit, the permittee must demonstrate that the alternative limit will assure protection of the BIP, considering the "*cumulative impact of its thermal discharge together with all other significant impacts on the species affected*." (40 CFR § 125.73(a)).

When applying for an alternative thermal limit, the permittee must submit the required supporting information and all demonstrations identified and described in 40 CFR § 125.72 and § 125.73. Among other things, the permittee must identify and describe:

1. The requested alternative thermal effluent limitation;
2. The methodology used to support that limitation;
3. The organisms comprising the BIP along with supporting data and information, and;
4. The types of data, studies, experiments and other information the applicant intends to use to demonstrate that the alternative thermal limit assures the protection and propagation of the BIP (40 CFR § 125.72(a) and (b)).

3.3 KEY DEFINITIONS

The significance of effects potentially caused by a thermal discharge, in both an ecological and regulatory sense, can be meaningfully assessed only in the context of established protection objectives, assessment endpoints, and assurance levels (USEPA 1974 and 1977). The following sections summarize the standards and criteria applicable under § 316(a) of the CWA and used in this Demonstration.

3.3.1 Balanced Indigenous Population

The method for evaluating the phrase "balanced indigenous population" or "BIP" is discussed in USEPA regulations, and the meaning of these terms has been further elaborated by the USEPA, Congress and the courts over the last several decades. The meaning of each of these three terms within the context of a § 316(a) Demonstration is discussed below.

Population -The USEPA has consistently recognized that the statutory term "population" which to biologists connotes interacting organisms of a particular species, is appropriately interpreted to mean "community," which connotes assemblages of populations based on ecological function. In promulgating final § 316(a) regulations, USEPA's Administrator stated:

> *The proposed regulations employed the term "balanced, indigenous population," as contained in the statute. Numerous objections were raised to USEPA's use of this phrase. Since the term "population" properly refers only to a single species, it is believed that the term*

> *"community" more accurately reflects the intent of the law. This term has therefore been substituted throughout the regulations. (39 Fed. Reg. 36,178 (8 October 1974)).*

Accordingly, USEPA's regulations provide for issuance of alternative thermal effluent limitations if "*a balanced indigenous community of shellfish, fish, and wildlife*", not necessarily particular populations within the community, will be maintained (40 CFR, 125.73(a); 44 Fed. Reg. 32,952 (7 June 1979)). These regulations define a "Balanced Indigenous Community" or "BIC" as:

> *"...a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and by lack of domination by pollution tolerant species. Such a community may include historically non-native species introduced in connection with a program of wildlife management and species whose presence or abundance results from substantial irreversible environmental modifications. Normally however, such a community will not include species whose presence or abundance is attributable to the introduction of pollutants that will be eliminated by compliance by all sources with section 301(b)(2) of the Act; and may not include species whose presence or abundance is attributable to alternative effluent limitations imposed pursuant to section 316(a)."*

To demonstrate that a BIC exists requires a case-by-case evaluation in the context of the specific waterbody and its biological community.

Indigenous - The term "indigenous" generally refers to the presence of species that would normally be found in the receiving waterbody; it is not restricted to only truly native species, since managed, introduced species are often included as "indigenous". "Indigenous" can also be interpreted to mean growing or living in the reference (control) body or stretch of water at the time the thermal impact determination is made.

The USEPA has interpreted the term somewhat more restrictively, but also acknowledges that "indigenous" does not mean communities that would exist in a waterbody only if it were in a pristine condition. In the preamble to its proposed § 316(a) rules, USEPA stated:

> *An "indigenous" population may contain species not historically native to the area which have resulted from major irreversible modifications to the water body (such as hydroelectric dams) or to the contiguous land area (such as deforestation attributable to urban or agricultural development) or from deliberate introduction in connection with a program of wildlife management. To qualify for an exemption under Section 316(a), it is therefore not necessary to show that the discharge is compatible with a population which may have existed in a pristine environment, but which has not persisted.* (39 Fed. Reg. 11,435 (28 March 1974); USEPA, Proposed Guidelines for Administration of the 316(a) Regulations (Draft 18 April 1974)).

USEPA thus would make reversibility of environmental modifications the "test" for determining what communities should be considered "indigenous" to the receiving waterbody. If modifications "*cannot reasonably be removed or altered*," then an "indigenous" community will include resulting "*species not historically native to the area*." (USEPA, 316(a) Technical Guidance - Thermal Discharges (Draft 30 September 1974)). On the other hand, "*an altered community which has resulted from pollution that will be corrected by compliance by all sources with Section 301(b)*" *[i.e., effluent limitations and standards] will not be considered "indigenous.*" (39 Fed. Reg. 36,178 (8 October 1974)).

Balanced - The term "balanced" derives from long-standing knowledge that most natural aquatic communities are composed of many species of organisms without an overwhelming number of any one of them. Ecologists have developed several formal indices (i.e., community assessment metrics) to assess the balance and structure of aquatic communities (e.g., indices of diversity, evenness, or richness). To be "balanced", USEPA has indicated that an aquatic community must not be "*dominated by pollution-tolerant species whose dominance is attributable to polluted water* *conditions.*" (39 Fed. Reg. 11,435 (28 March 1974); 40 CFR 125.71(c), 44 Fed. Reg. 32,951-52 (7 June 1979)).

However, species diversity at each trophic level is not required, and some changes in species composition and abundance are consistent with a balanced community. (39 Fed. Reg. 36,178 (8 October 1974)). According to USEPA, the following are evidence of community imbalance:

- Blocking or reversing short or long-term successional trends of community development.
- A flourishing of heat-tolerant species and an ensuing replacement of other species characteristic of the indigenous community.
- Simplification of the community and the resulting loss of stability.

If a community is stable, not dominated by heat-tolerant species, and follows normal development patterns, it is considered "balanced".

In summary, a BIC is a stable, normally functioning community that is not dominated by heat-tolerant species and is consistent with the reasonably permanent environmental conditions of the waterbody, given potential water quality improvement. An indigenous population of aquatic organisms does not mean that those organisms must be representative of "pristine" conditions in the waterbody. Similarly, a balanced community is one that exhibits structural, functional, and cyclical patterns that are typical for the waterbody and similar waterbodies.

3.3.2 Protection and Propagation

The legislative history of § 316(a) and the subsequent judicial and administrative decisions applying it make clear that the thermal discharge performance standard – the protection and propagation of a BIC – is not to be interpreted as a complete lack of observable effects on that aquatic community. Some effects of added heat to a receiving waterbody are to be expected, especially at the point of discharge and within the designated thermal mixing zone. For example, USEPA has recognized that "*[e]very thermal discharge will have some impact on the biological community of the receiving water,*" *and therefore that "[t]he issue is the magnitude of the impact and its significance in terms of the short-term and long-term stability and productivity of the biological community affected*" (Boston Edison Company (Pilgrim Station Units 1 and 2), NPDES Permit Determination No. MA0025135 (Decision of the Regional Administrator, 11 March 1977)).

In general, USEPA has determined that a community need not be protected from mere disturbance, but rather that communities will be adequately protected if "Appreciable Harm" is avoided (USEPA, NRC, and FWS, 316(a) Technical Guidance Manual (Draft 11 December 1975)).

3.3.3 Appreciable Harm

The § 316(a) implementing regulations identified in 40 CFR Part 125, Subpart H, along with administrative and legal precedents, identify the following decision criteria for use in evaluating whether "Appreciable Harm" has occurred and whether a BIC is present in the area receiving the thermal discharge (Coutant 2018).

- Presence of all trophic levels
- Presence of necessary food chain species
- Diversity
- Capability to sustain itself
- Lack of domination of pollution (heat) tolerant

- No increase in nuisance species
- Increase or decrease of indigenous species
- No decrease in threatened and/or endangered species
- No habitat exclusion due to temperature
- Maintenance of a zone of passage
- Change in commercial or sport species
- Biological data on key species
- No habitat former alterations
- Magnitude and duration of any identifiable thermal effects
- Sublethal or indirect effects
- No thermal effects on rare or unique habitats
- Presence of critical function zones within thermally exposed areas
- Trends in the aquatic community
- Interaction of the thermal discharge with other pollutants

Thus, an acceptable ATEL is one that will not result in changes so substantial that would cause community imbalance, elimination, or replacement and thus provides adequate protection against appreciable harm. USEPA has indicated that other relevant factors in determining whether the BIC will be adequately protected include the nature of the waterbody, the risks posed by alternate cooling technologies, the age and remaining useful life of the generating facility, and the nature of the surrounding area (USEPA, 316(a) Technical Guidance - Thermal Discharges Draft 30 September 1974)).

3.3.4 Reasonable Assurance

The standard of proof under § 316(a) is one of "Reasonable Assurance", not scientific certitude, because there are seldom, if ever, cases where such certitude is achievable in the quantification of environmental effects or their significance to biological communities. USEPA has described this standard of proof as follows:

> *The study must provide reasonable assurance of protection and propagation of the indigenous community. Mathematical certainty regarding a dynamic biological situation is impossible to achieve, particularly where desirable information is not obtainable. Accordingly, the Regional Administrator (or Director) must make decisions on the basis of the best information reasonably attainable. At the same time, if he finds that the deficiencies in information are so critical as to preclude reasonable assurance, then alternative effluent limitations should be denied."* (USEPA, 316(a) Technical Guidance - Thermal Discharges (Draft 30 September 1974)).

USEPA has applied the "Reasonable Assurance" standard in numerous decisions implementing § 316(a).[1]

[1] Public Service Company of New Hampshire (Seabrook Station Units 1 and 2), NPDES Appeal No. 76-7 (Decision of the Administrator, 10 June 1977) at 22; Public Service Company of New Hampshire, et al., (Seabrook Station Units 1 and 2), NPDES Appeal No. 76-7 (Decision on Remand, 4 August 1978) at 22; Boston Edison Company (Pilgrim Station Units 1 and 2), NPDES Permit Determination No. MA0025135, Decision of the Regional Administrator, 11 March 1977) at 15-16; Boston Edison Company (Pilgrim Station Units 1 and 2), NPDES Appeal No. 78-7 (Initial Decision, 26 July 1978) at 4-5.

3.4 DEMONSTRATION STRUCTURE AND ORGANIZATION

Demonstrating that the BIC will be protected under the proposed ATEL is typically conducted in four steps:

1. Evaluating each biotic category for low potential impact;
2. Evaluating evidence for prior appreciable harm;
3. Predicting the potential for impact to Representative Important Species (RIS); and,
4. Preparation of a Master Rationale to support the requested alternative thermal limits.

Each of these steps are the focus of the subequent sections of this Demonstration.

4. BIOTIC CATEGORY RATIONALES

In preparing regulatory guidance for § 316(a) variance requests, USEPA recognized that not all components of an aquatic ecosystem are equally vulnerable to the potential effects of thermal discharge. As a result, USEPA included in their draft guidance (USEPA 1977) recommendations for a screening process to identify those components that have a low potential for impact and allow the subsequent analysis to focus on those components of greatest risk. This guidance recommends dividing the biological community into six biotic categories based on the types of organisms, the habitat resource zone they occupy, and their role in the community food web:

- phytoplankton,
- zooplankton (including meroplankton),
- habitat formers,
- benthic macroinvertebrates (including shellfish),
- fish, and
- other vertebrate wildlife.

The Guidance Manual (USEPA 1977) further recommends that facilities conduct pilot field investigations and literature searches to determine if a site is one of low potential impact (LPI) for one or more of the individual biotic categories.

Often these initial investigations will be sufficient to determine if a site is an area of LPI or if additional studies are necessary to respond to the decision criteria presented in Section 3.3 of the Guidance Manual and develop the rationales for the six biotic categories. These rationales evaluate the available scientific information relative to the decision criteria for each biotic category to determine whether a site is an area of LPI. Thermal discharges to sites successfully meeting the area of LPI decision criteria under this early screening process pose little potential threat to the biotic category or categories for which the criteria are met. Those discharges not meeting the decision criteria to qualify as a site of LPI for one or more biotic categories are required to conduct additional studies to determine if the proposed alternative thermal limits will still be protective of the BIC.

For each of the six-biotic categories described in the Guidance Manual, the following sections characterize the community present in the LMOR in the vicinity of the LEC, present the applicable decision criteria for determining an area of LPI, and develop a rationale responsive to these criteria based upon the information presented. More specifically, each element of the biotic category sections includes:

- **Category Characterization**: provides a general description of the biotic category based on available data from the vicinity of the LEC, the LMOR, or another large river with similar characteristics to that of the Missouri River. The information presented is based on available literature and/or prior studies to characterize the major/dominant forms present, fluctuations in population and/or structural dynamics, non-thermal factors affecting the biotic category (e.g., water quality, habitat modifications, introduction of non-native forms), and potential exposure to the thermal plume.
- **Decision Criteria**: identifies and describes the area of LPI decision criteria as it relates to the biotic category in question.
- **Rationale**: provides the justification and basis for whether the LPI criteria are satisfied. For biotic categories that do not meet the LPI criteria, the additional field studies, NPAH decision criteria, and biotic category rationales are presented in Section 5.

4.1 PHYTOPLANKTON

4.1.1 Category Characterization

Phytoplankton are microalgae that inhabit the photic zone (i.e., upper water column) of waterbodies such as rivers, lakes and oceans. Phytoplankton growth is favored in habitats with good light availability, adequate nutrients, and relatively high residence time (Bukaveckas et al. 2011), such as lakes, reservoirs and bays.

Most phytoplankton rely on currents to keep them afloat and carry them through the waterbody and can be the base of some aquatic food webs (NOAA 2017), though food webs in many rivers are detrital based (USACE 1974). Many rivers, such as the Missouri River, exhibit high turbidity levels which decreases light availability and swift water currents that reduce residence time, typically resulting in limited phytoplankton growth (Hesse et al 1982). In addition, the higher water velocities found in many rivers can limit resource utilization efficiency by reducing opportunities for individual phytoplankton cells to utilize growth factors like ambient nutrients (Bukaveckas et al. 2011) leading to reduced overall phytoplankton biomass (Paerl et al. 2006). Due to these habitat attributes, large riverine systems such as the Missouri River have a food web based heavily on detritus, rather than on phytoplankton (Hesse et al 1982). River phytoplankton typically exhibit lower species richness and reduced biomass relative to lake phytoplankton (Rojo et al. 1994).

Equitable Environmental Health (EEH 1976) collected phytoplankton in the vicinity of LEC on five dates in 1974 (July 29, August 29, September 26, October 24 and November 22) and three dates in 1975 (April 22, May 22 and June 19). The following phytoplankton phyla were collected:

- Bacillariophyta (diatoms)
- Chlorophyta (green algae)
- Cyanophyta (blue-green algae)
- Euglenophyta
- Pyrrophyta (dinoflagellates)

The EEH study concluded that the relatively low abundance of phytoplankton in the vicinity of LEC was due to the absence of taxa intolerant of high river flow and turbid water conditions (UEC 1976).

Studies of phytoplankton conducted monthly from 1974 – 1977 in the middle Missouri River (RM 646 – 532.5; the LEC is located near RM 57) by Reetz (1982) observed, in addition to the above, the following two additional phyla:

- Cryptophyta
- Chrysopyhta

Compositional patterns were similar to that observed by EEH (1976). Diatoms dominated the community throughout much of the year (especially in winter and spring). Green algae were usually present in Reetz's sample collections, increasing in number in mid to late summer. Blue-green algae were important components of the community in summer, as cryptophytes were in winter. Chrysophytes, euglenoids, and dinoflagellates were usually present in small to moderate numbers throughout the year. This composition was influenced by discharges of water and associated lentic phytoplankton from Lewis and Clark Lake, an upstream main-stem reservoir and population source for downstream phytoplankton.

Dzialowski et al. (2013) conducted a study comparing phytoplankton in backwater, chute, and mainstem environments in the LMOR (survey range RM 183-660). The sampling station in the study nearest the LEC (RM 57) was at USGS gage 06909000 at RM 197. The study found that diatoms made up the majority of the phytoplankton in all three habitats. Diatoms are more tolerant of the turbid conditions typical of the Missouri River than other phytoplankton taxa. Chlorophyta, cyanobacteria, Cryptophyta, and Euglenophyta were present but decreased in abundance as turbidity increased. The 1974-1975 EEH study similarly found the phytoplankton dominated by diatoms (> 90 percent of the observed biomass) with Chlorophyta, cyanobacteria, Cryptophyta, and Euglenophyta also present in reduced numbers.

The available studies summarized above show that the composition of the phytoplankton component present within the vicinity of the LEC is similar to that found throughout the Missouri River.

4.1.2 Decision Criteria

The USEPA has established criteria to determine if a site is an area of LPI for phytoplankton. Areas of LPI for phytoplankton are defined as systems in which phytoplankton is not the base of the food chain. The Guidance Manual states that most rivers and streams fall into this category (USEPA 1977). An area can be considered LPI if it meets the following criteria:

- Phytoplankton are not the food chain base of the system and do not contribute a substantial amount of the primary photosynthetic activity supporting the community;
- The thermal discharge would not encourage a shift toward nuisance species; and
- Operation of the discharge would not alter the community from a detrital to a phytoplankton-based system (USEPA 1977).

4.1.3 Phytoplankton Rationale

Criterion: *Phytoplankton are not the food base of the river system.*

The Missouri River, like many other lotic systems, is based on detritus, rather than phytoplankton (Hesse 1982).

Criterion: *The thermal discharge would not encourage a shift toward nuisance species.*

Nuisance phytoplankton species are so-called because they can react to stimulants like strong light, high nutrient concentrations, and elevated water temperatures with a sudden, rapid increase in growth called blooms. These blooms can result in unsightly algal mats, unpleasant odors or taste, and in some instances, toxins produced as metabolic by-products of the bloom species. Additionally, as the nuisance species die, the individual organisms sink to the bottom of the water column where they are metabolized by bacteria and micro-organisms. This process consumes ambient dissolved oxygen which can become depleted when large numbers of dead organisms are metabolized after a bloom.

Light availability, reduced by the turbid nature of the Missouri River typically limits the potential for excessive growth of phytoplankton (Hesse et al. 1982; Bukaveckas et al. 2011), including nuisance species. Unlike phytoplankton in lakes and reservoirs, phytoplankton in rivers are constantly transported downstream by the river current; therefore, individual organisms are not resident to the area for a prolonged time and would experience very limited exposure to the LEC thermal discharge. Hydrothermal modeling conducted by Kleinfelder predicts that free-drifting organisms would take approximately an hour and a half to pass through the thermally exposed zone at river flows ranging from 38,000 cfs to 68,000 cfs. If a bloom event does occur in a river, it is typically short in duration, due to dissipation of the phytoplankton by river currents (Marshall, no date).

Due to the transient exposure of phytoplankton to the LEC thermal discharge and lack of a "resident" diverse algal population due to constant downstream transport, the LEC thermal discharge will not result in a shift towards a dominance of nuisance species. In addition, temperatures rapidly decline after the confluence of the LEC discharge canal with the Missouri River. Typically, temperatures within the thermal plume are less than 5°F above ambient by 0.25 miles downstream of the discharge canal and continue to decrease with distance downstream. These moderately elevated temperatures are also not sufficiently high to result in changes in the phytoplankton community.

Criterion: *Operation of the discharge would not alter the food web from a detrital to a phytoplankton-based system.*

The thermal plume would not alter the LMOR from its current detrital-based system to a phytoplankton-based one. Phytoplankton growth in waterbodies is strongly influenced by light availability and residence time (Bukaveckas et al. 2011). Given the limited light availability (resulting from high turbidity), strong water currents prevalent in the LMOR that discourage phytoplankton growth (UEC 1976), and limited exposure that the phytoplankton population has to the thermal plume (due to swift downstream transport), the LEC discharge would not cause a shift in the river from the current detrital-based food web to a phytoplankton-based one.

To summarize, a review of the available studies and literature show that the Missouri River has a detrital-based food web and not one based on phytoplankton productivity primarily due to the high turbidity and flows which limit phytoplankton growth. Further, phytoplankton are exposed to the LEC thermal plume, mostly at temperatures less than 5°F above ambient, for only a short period of time (typically less than 1.5 hours) due to the constant downstream transport. These factors also limit the potential for a shift towards nuisance phytoplankton taxa and the potential for the Missouri River to become a phytoplankton-based food web. Therefore, the area of the Missouri River receiving the LEC thermal discharge satisfy the criteria for classification as an area of LPI for phytoplankton.

4.2 ZOOPLANKTON AND MEROPLANKTON

4.2.1 Category Characterization

Zooplankton are small, common, heterotrophic organisms that inhabit freshwater, brackish, and marine environments and consist of two subgroups: holoplankton and meroplankton. Holoplankton spend their entire lives as plankton. Meroplankton are small, generally early life-stage organisms that only spend this early life-stage in a planktonic form (e.g., shellfish and fish eggs and larvae). Generally, meroplankton will experience similar exposure to a thermal discharge as zooplankton. Zooplankton consume phytoplankton and other organic material, regenerate nutrients, and transfer energy to higher trophic levels in the food web. Freshwater zooplankton are typically composed of rotifers, copepods, and cladocerans (Havel et al. 2009). Rotifers are usually the dominant zooplankton group in rivers. While copepods and cladocerans are present in rivers, they are more abundant in still water environments such as lakes, ponds, and reservoirs (Hynes 1970). Havel et al. (2009) concluded that the lower abundance of copepod and cladocerans in rivers was due in part to reproductive rates too slow to compensate for the mortality these taxa typically experienced in swift river environments.

Zooplankton densities in the LMOR and other rivers are typically low (Dzialowski et al. 2013). Rivers present environmental conditions such as high-water current velocity and elevated ambient levels of suspended particles (i.e. turbidity) that are not conducive to zooplankton growth (Repsys and Rogers 1982). Additionally, most zooplankton have a limited capacity to tolerate the physical buffeting planktonic organisms experience in waterbodies with higher current velocities and turbulence (Repsys and Rogers 1982).

Reservoir discharges are the source of most of the zooplankton found in rivers (Hynes 1970; Havel et al. 2009) and zooplankton abundance typically decreases with distance from these impoundments. Studies by Williams (1971) and Kallemeyen et al. (1977) showed a reduction of 70 percent in zooplankton density 90 miles below the Lewis and Clark Lake (RM 811.1) tailwaters in the Missouri River. While tributaries, backwater areas, and floodplains can also serve as sources of river zooplankton, Dickerson et al. (2009) and Fisher (2011) cited channelization of the LMOR as having largely disconnected the river from floodplains and other backwater areas that previously served as sources of zooplankton to the river. In addition, Havel et al. (2009) found that Missouri River tributaries, on average, contributed little to main stem zooplankton populations. Other potential sources of zooplankton in the Missouri River have been shown to be limited (Havel et al. 2009).

Several zooplankton studies have been conducted within various reaches of the Missouri River and form the basis for characterizing the zooplankton component near the LEC. Consistent with the descriptions of the zooplankton composition discussed above for rivers in general, the Missouri River studies have shown that copepods, cladocerans, and rotifers are the most commonly observed zooplankton taxa. Copepods and cladocerans were more abundant in the upper and middle Missouri River while rotifers were more abundant in the lower, channelized section of the river (Havel et al. 2009; Dickerson et al. 2009; Repsys and Rogers 1982).

As part of the original § 316(a) demonstration studies for the LEC, EEH (1976) collected zooplankton in the Missouri River at the LEC (RM 57.5) in 1974 and 1975. Samples showed zooplankton composition consisted primarily of rotifers, cladocerans, and copepods, similar to the composition found in other Missouri River studies. The overall abundance of zooplankton at the LEC was described as low and the distribution was noted as patchy (UEC 1976).

Zooplankton taxa of commercial importance or rare or endangered zooplankton taxa were not observed or identified in any of the Missouri River studies discussed above and are not known to be present in the river.

4.2.2 Decision Criteria

Areas of LPI for zooplankton are defined as those characterized as having low concentrations of commercially important species, no rare and endangered species and/or those forms that are important components of the food web; or where the thermal discharge will affect a relatively small proportion of the receiving waterbody.

4.2.3 Zooplankton Rationale

The Guidance Manual states that rivers and streams typically have low concentrations of zooplankton, and that most of these waterbodies can be considered areas of LPI (USEPA 1977). Union Electric Company (UEC 1976) found the Missouri River to have a low standing crop of zooplankton. Zooplankton of commercial importance or threatened or endangered zooplankton taxa have not been observed in the studies surveying the LMOR as discussed in Section 4.2.1.

The LEC thermal discharge also affects a relatively small portion of the LMOR, the LEC discharge is typically less than 5 percent of the river flow, and zooplankton and meroplankton drifting downstream would only be exposed to the thermal plume for a brief period of time. Hydrothermal modeling conducted by Kleinfelder predicts that free-drifting organisms would take approximately an hour and a half to pass through the thermally exposed zone at river flows ranging from 38,000 cfs to 68,000 cfs.

For these reasons, the LMOR in the vicinity of the LEC meets the Guidance Manual criteria as an area of LPI for zooplankton and meroplankton. The ichthyoplankton (fish eggs and larvae) component of meroplankton are further addressed in via the predictive assessment in Section 6.

4.3 HABITAT FORMERS

4.3.1 Category Characterization

Habitat formers are any assemblage of plants and animals characterized by a relatively sessile (stationary) life stage with aggregated distribution on which other organisms attach or with which they associate (USEPA 1977). The USEPA (1977) further defines habitat formers as:

1. *"A living and/or formerly living substrate for the attachment of epibiota;*
2. *Either a direct or indirect food source for the production of shellfish, fish, and wildlife;*
3. *A biological mechanism for the stabilization and modification of sediments and contributing to the development of soil;*
4. *A nutrient cycling path or trap; or*
5. *Specific sites for spawning and providing nursery, feeding and cover areas for fish and shellfish."*

Within the Missouri River, habitat formers may include any group of plants or animals which are attached to the river bottom and provide suitable substrate or other critical habitat characteristics for other organisms (UEC 1976). Examples include submerged and emergent aquatic vegetation (SAV and EAV). Surveys conducted as part of the 1976 LEC § 316(a) demonstration (UEC 1976) identified the river's velocity, turbidity, silty substrate, and rip-rap shoreline banks as likely limiting factors to the colonization and development of habitat formers in the vicinity of the LEC discharge (UEC 1976). Silt substrate is unstable and highly susceptible to washout under the high velocity conditions found in the channelized sections of the LMOR (EEH 1976). The surveys found the main channel silty substrate, rip-rap shorelines and low light penetration (i.e. turbidity) did not support the growth of aquatic vegetation (EEH 1976). Angradi et al. (2009) also found that much of the lower river was devoid of submerged aquatic vegetation.

Additionally, due to the historic channelization of the LMOR and the relatively uniform shoreline in the vicinity of the LEC, suitable habitats for spawning or nursery areas for many fish species in the river were not identified (EEH 1976). The current channel morphology of the LMOR in the vicinity of the LEC remains dominated by channelization with rock wing dikes and revetments constructed as part of the Missouri River Bank Stabilization and Navigation Project (Ferrell 1996). These alterations to the channel and flow regime continue to result in changes to the habitat diversity and availability, which has resulted in decreases in fish populations, and native flora and fauna (Johnson et al. 2006; Bryan et al. 2010). Throughout the two years of sample collection under the current Study Plan, no established SAV or EAV communities were observed in any part of the study area.

4.3.2 Decision Criteria

The Guidance Manual provides that areas of LPI for habitat formers are those that are typically devoid of habitat formers. LPI sites may be devoid of habitat formers due to low levels of nutrients, inadequate light penetration, sedimentation, scouring stream velocities, unsuitable substrate character, or the presence of toxic materials (USEPA 1977). Should these factors or physical conditions limiting the habitat formers presence change, the USEPA (1977) defines a site as an area of LPI if the heated discharge would not restrict the reestablishment of habitat formers. LPI sites for habitat formers are also defined as sites that do not pose a danger to threatened or endangered species of other biotic categories from an adverse impact on habitat formers.

4.3.3 Habitat Formers Rationale

The 1976 LEC § 316(a) demonstration (UEC 1976) found that the area within the vicinity of the thermal discharge was devoid of habitat formers due to the river's velocity, turbidity, and silty substrate which were limiting factors to the colonization and development of habitat formers. These limiting environmental conditions are still present today, as is the continued channelization and steep shorelines armored with riprap found throughout the LMOR, which do not support the growth of aquatic vegetation (Ferrell 1996). Based on the physical alterations and persistently unstable substrate conditions of the riverine environment that continue in the LMOR, it is suspected that the absence of habitat formers in the vicinity of the Labadie thermal discharge is unrelated to the discharge and would not change if the discharge were reduced or terminated. The LEC site is devoid of habitat formers and likely to remain so, therefore, the area of the LMOR receiving the LEC thermal discharge satisfies the decision criteria as a site of LPI.

4.4 MACROINVERTEBRATES/SHELLFISH

4.4.1 Category Characterization

Benthic macroinvertebrates are organisms that live in and on the bottom and shoreline substrates of waterbodies where they play an important role in providing food, nutrient cycling, and energy transfer in the food webs of freshwater and marine ecosystems. These organisms may be permanent residents in the substrate or temporary ones such as the larval stages of insects. This biotic category includes shellfish, which in freshwater environments are primarily represented by mussels and clams, but also includes crustaceans such as crayfish.

Substratum-type is the primary factor controlling benthic macroinvertebrate distribution, e.g., chironomids (midgeflies) and oligochaetes (aquatic worms) are commonly found in depositional areas with fine-grained sediments (Hynes 1970; Wolfe et al. 1972). Swift river currents can reduce sediment stability and increase turbidity; conditions which have been shown to limit the development of macroinvertebrate communities and are often associated with low numbers of benthic infauna (Carter et al. 1982; Hynes 1970). Currents and substrate are also known to influence freshwater mussel distribution (Hoke 2009).

As part of the original LEC § 316(a) demonstration studies, EEH conducted surveys of the benthic macroinvertebrate component in the vicinity of the LEC in 1974-1975 using artificial substrate [modified Hester-Dendy (H-D)] samplers, a petite Ponar grab, and a plankton net to collect samples.

Overall, the macroinvertebrate composition varied by substrate type represented by the different collection methods. The macroinvertebrates sampled using the artificial substrate samplers were dominated by caddisflies (order Trichoptera) and midgeflies (order Diptera, family Chironomidae), which together represented approximately 91 percent of the organisms collected (EEH 1976). Drift samples collected 34 macroinvertebrate taxa from two phyla with a genus (*Polypedilum*) of midgefly representing the most prevalent taxa, accounting for approximately 25 percent of the total number of organisms collected. Benthic macroinvertebrates in grab samples were represented by 17 taxa from four phyla. Oligochaetes (aquatic worms) were the most prevalent taxa among the samples.

UEC (1981) conducted a 1-year benthic macroinvertebrate survey in the vicinity of the LEC using a standard Ponar grab sampler. A total of 51 macroinvertebrate taxa were collected with tubificid oligochaetes accounting for approximately 84 percent of the total number of organisms. Chironomidae accounted for only 5 percent of the organisms collected. No commercially important, rare or endangered species were collected during the study. Macroinvertebrates identified were consistent with that expected for a fine sand/silt substrate habitat and were similar to those reported in other Missouri River studies (UEC 1981).

Findings from other studies on the LMOR are consistent with those found in the studies conducted near the LEC showing macroinvertebrate composition influenced primarily by substrate type. Surveys by USGS (2010), Poulton et al. (2002), MDNR (2014), and Carter et al. (1982) all found macroinvertebrates sampled by artificial substrate samplers were dominated by Trichoptera with additional prevalent taxa including mayflies (order Ephemeroptera), stoneflies (order Plecoptera), and Chironomidae. In depositional areas (e.g., dike pool habitats) characterized by fine grained sediments, these studies found the macroinvertebrates were dominated by Oligochaeta and Chironomidae. Poulton and Allert (2012) also found Oligochaeta to be the dominant taxa in petite Ponar samples with substantial contributions from Chironomidae and burrowing Ephemeroptera.

Similar to the sampling conducted in the vicinity of the LEC, none of the studies referenced above collected any macroinvertebrate species of commercial importance or that are threatened or endangered (T&E).

Shellfish are grouped into the benthic macroinvertebrate biotic category by the USEPA. The flow (swift and turbid) and substrate characteristics (hard bottom or silt/clay) of the LMOR do not provide ideal habitat for shellfish. EEH (1976) found that shellfish were not commonly collected and were represented by one gastropod (snail) genus (*Physa* sp.) and one species of fingernail clam (*Sphaerium striatinum*) collected on artificial substrate samplers on one date in the discharge canal. The same clam species was collected in Ponar grab samples in June and October (a total of 9 individuals). During the UEC (1981) survey, no freshwater mussels (Unionidae) were collected, but several species of freshwater fingernail clams and snails were found. The fingernail clam, *Sphaerium striatinum*, was the most abundant shellfish taxon collected representing approximately 2 percent (162 organisms) of the total macroinvertebrates collected. The other LMOR studies reviewed above made no specific mention or discussion of shellfish (mussels and/or clams).

In addition to previous studies, three qualitative visual surveys for shellfish were conducted in 2017 and 2018 to supplement Ponar grab sampling to look for the presence of any T&E shellfish species. No live shellfish were observed or collected during any of the visual surveys conducted for the LEC in 2017 and 2018. The various shells observed and recorded are presented in Table 4-1 for the three individual surveys. No T&E shellfish species were collected in the Ponar samples and no shells of T&E shellfish were observed during the visual surveys.

Shellfish species of commercial importance or that are T&E were not collected during any of the historical sampling conducted in the vicinity of the LEC, the other LMOR studies discussed above, or in the current study.

4.4.2 Decision Criteria

The USEPA (1977) defines an area of LPI for macroinvertebrate/shellfish fauna as one which, within the primary and far-field study areas, can meet the following requirements as specified in the Guidance Manual:

1. Macroinvertebrate/shellfish species of existing or potential commercial value do not occur at the site.
2. Macroinvertebrate/shellfish do not serve as important components of the aquatic community at the site.
3. T&E species of macroinvertebrate and/or shellfish do not occur at the site.
4. The standing crop of macroinvertebrate/shellfish at the time of maximum abundance is less than one-gram ash-free dry weight per square meter.
5. The site does not serve as a spawning or nursery area for the species in 1, 2, or 3 above.

Table 4-1 Result of visual mussel survey on September 15, December 7, 2017 and June 14, 2018.

		Zone 1			**Zone 2**			**Zone 3**			**Zone 4**		
Common Name	***Scientific Name***	**Sep-17**	**Dec-17**	**Jun-18**	**Sep-17**	**Dec-17**	**Jun-18**	**Sep-17**	**Dec-17**	**Jun-18**	**Sep-17**	**Dec-17**	**Jun-18**
Asian Clam	*Corbicula fluminea*	A, C	A	A, C	A		R	A, C	A, C	A, C	C, U	A, C	A, C
Zebra Mussel	*Dreissena polymorpha*		A	C, U				R	U	C, U		U	U, R
Fragile papershell	*Leptodea fragilis*	U	C					U, R	C	U, R		U	
Treehorn Warty back	*Obliquaria reflexa*		U							R			
Round pigtoe	*Pleurobema coccineum*							R					
Mapleleaf	*Quadrula quadrula*										R		
Mucket	*Lampsilis sp.*		U										
Pink heelsplitter	*Potamilus alatus*	U								R	U		R
Giant Floater	*Pyganodon grandis*		U	R						U			U

Relative Abundance Codes: A - Abundant, C - Common, U - Uncommon, R – Rare
Note: No live specimens were encountered. Taxa and relative abundances were based off of observed shells.

4.4.3 Macroinvertebrates/Shellfish Rationale

Criterion: *Macroinvertebrate/shellfish species of existing or potential commercial value do not occur at the site.*

Commercially valuable riverine macroinvertebrates primarily include certain freshwater mussel species and some varieties of snails and crayfish. None of the macroinvertebrates or shellfish collected by EEH (1976) or UEC (1981) in the vicinity of LEC were of commercial importance, and none are otherwise known to exist. Similarly, macroinvertebrate species of commercial importance were not collected in the current study or the other studies reviewed.

Criterion: M*acroinvertebrates/shellfish do not serve as important components of the aquatic community at the site.*

Although benthic invertebrates are typically important components of food webs, the lower, channelized section of the Missouri River supports relatively low numbers of benthic organisms, including the area of the river in the vicinity of LEC (EEH 1976, UEC 1981). Even though macroinvertebrate abundance may be low, they still provide an important food source for fish.

Criterion: *Threatened or endangered species of macroinvertebrate/shellfish do not occur at the site.*

Surveys in the vicinity of the LEC conducted by EEH (1976) and UEC (1981) found no evidence of T&E macroinvertebrate or shellfish species.

Criterion: *The standing crop of macroinvertebrates/shellfish at the time of maximum abundance is less than one-gram ash-free dry weight per square meter.*

Although the abundance of benthic invertebrates in the vicinity of the LEC has been described as low (EEH 1976, UEC 1981), information regarding standing crop is not available. Data from the current two-year study shows that mean seasonal benthic macroinvertebrate densities across all zones ranged from approximately 140 organisms per square meter to 9480 organisms per square meter. These numbers suggest that benthic macroinvertebrate standing crop likely exceeds one-gram ash-free dry weight per square meter.

Criterion: *The site does not serve as a spawning or nursery area for the species that are commercially valuable, rare or endangered, or important components of the food web.*

No commercially valuable or T&E benthic macroinvertebrate or shellfish species have been found in the surveys conducted near the LEC and there is no evidence that these species rely on the area directly exposed to LEC's thermal discharge for reproduction. However, areas behind dike fields downstream of the LEC thermal discharge may contribute to macroinvertebrate/shellfish reproduction and are potentially exposed to the thermal plume.

While the area of the LMOR receiving the LEC thermal discharge meets most criteria for an area of LPI for benthic macroinvertebrates, this subcomponent does represent an important food source for fish and is potentially exposed to the LEC thermal discharge. Therefore, benthic macroinvertebrates are a component of the ongoing biological assessment and addressed in detail relative to the Guidance Manual NPAH decision criteria in Section 5 of this Demonstration report.

On the other hand, shellfish occur only rarely in the vicinity of the LEC thermal discharge and, hence, have little potential for exposure to the thermal plume. Thus, the area of the LMOR receiving the LEC thermal discharge satisfies the decision criteria as a site of LPI for shellfish and therefore shellfish are not addressed further.

4.5 FISH

4.5.1 Category Characterization

Numerous studies of Missouri River fishes have been conducted to determine the long-term effects of river habitat modification on this community component. The most comprehensive study known as the Benthic Fishes Study (BFS) was conducted from 1995–1999 by a consortium consisting of the USGS Cooperative Fishery Units in six states along the Missouri River (Idaho, Montana, South Dakota, Kansas, Iowa, and Missouri), the Columbia Environmental Research Center, and the Montana Department of Fish, Wildlife and Parks (Berry and Young 2001; Galat et al. 2005b; Berry et al. 2004; Pierce et al. 2003). The BFS included the mainstem river from its source to its mouth at the Mississippi River (excluding the mainstem reservoirs). The study area was divided into a total of 27 segments, the last two of which (Segments 25 and 27) bracket the river reach where the LEC is located (RM 57.5). The study features detailed data on distribution, abundance, growth, mortality, recruitment, condition, and population size structure for 26 target benthic fish species.

Under the previous § 316(a) demonstration program, sampling targeting adult fish was conducted near the LEC CWIS and discharge canal (UEC 1976). More recent fisheries surveys (1980–1985 and 1995–2001) have been conducted by Ameren to establish a long-term database on fish composition and abundance in the river near the LEC in order to detect possible changes associated with plant operation or other factors, including river channelization and low flows during the drought of 1988–1992 (Ameren 1998, 2002). Parameters evaluated under this study included species composition, species diversity, species assemblage persistence, relative abundance, catch-per-unit-effort, fish size and condition, Pflieger faunal composition characterization, and individual fish movements through tag recaptures.

The Missouri River fish species composition varies longitudinally from the headwaters to its confluence with the Mississippi River at St. Louis (Berry et al. 2004). Berry and Young (2001) identified 156 fish species occurring in the entire Missouri River Basin and Galat et al. (2005b) found 136 species occurring in the mainstem, floodplains, and reservoirs and of these, 110 species were listed for the LMOR. The changing ecosystem and habitat losses during recent decades has decreased the abundance of many native species to rare or uncommon across part or all of their previous ranges (NRC 2002). It was estimated by Berry and Young (2001) that approximately 35 native species are declining in abundance, while 23 species (14 native and 9 introduced) are increasing.

Important sportfish species within the vicinity of the LEC, include the channel catfish, flathead catfish, blue catfish, sauger, walleye, white bass, striped bass, largemouth bass, smallmouth bass, spotted bass, white crappie, black crappie, and various sunfish species. Commercially exploited species have included common carp, channel catfish, bigmouth buffalo, smallmouth buffalo, flathead catfish, goldeye, and members of the sucker family (Catostomidae). Since July 1992, commercial fishing for catfish species in the Missouri River (flathead catfish, blue catfish, and channel catfish) has been prohibited due to a decline in the number of large fish (Berry and Young 2001).

Gizzard shad were found to be the most abundant species collected in both the BFS and Ameren studies and comprised 42 percent and 55 percent of the total catches, respectively. Almost all minnow, chub, and shiner species collected in the BFS were absent from the Ameren study (Ameren 2002) catches; this includes emerald shiner, which was the second-most frequently caught species in the BFS. This absence was most likely due to the habitats selected for sampling or low sampling efficiency of the electrofishing gear for small species during the Ameren study. In the BFS, many of the small cyprinid species were caught by seines in shallow or backwater areas (Berry et al. 2004). Other common species collected during the BFS and Ameren studies, in decreasing order of abundance, include river carpsucker, freshwater drum, channel catfish, common carp, shortnose gar, and flathead catfish (ASA 2008). Another recent source (USACE 2006) has identified these species as being dominant, in addition to red shiner and goldeye.

4.5.2 Decision Criteria

The Guidance Manual provides that the fish section of a § 316(a) demonstration will be successful if it can show that the site is an area of LPI for fish. An area receiving a thermal discharge would be determined as a site of LPI if the following conditions within the primary and far-field study area as stated by USEPA (1977) are met:

1. The occurrence of sport and commercial species of fish is marginal;
2. This discharge site is not a spawning or nursery area;
3. The thermal plume (bounded by the 3.6°FC isotherm) will not occupy a large portion of the zone of passage which would block or hinder fish migration under the most conservative environmental conditions (based on 7-day, 10-year low flow or water level and maximum water temperature);
4. The plume configuration will not cause fish to become vulnerable to cold shock or have an adverse impact on threatened or endangered species.

4.5.3 Fish Rationale

In order for the LMOR in the vicinity of the LEC to meet the criteria for an area of LPI, the occurrence of sport and commercial fish species within that area must be minimal along with the presence of spawning and nursery areas. However, important sportfish species were identified within the vicinity of the LEC during several previous studies and include channel catfish, flathead catfish, blue catfish, sauger, walleye, white bass, striped bass, largemouth bass, smallmouth bass, white crappie, black crappie, and sunfish species. Commercially exploited species identified within the vicinity of the LEC include common carp, channel catfish, bigmouth buffalo, smallmouth buffalo, flathead catfish, goldeye, and members of the sucker family, Catostomidae. However, since July 1992, commercial fishing for catfish species in the Missouri River (flathead catfish, blue catfish, and channel catfish) is prohibited due to a decline in the number of large fish (Berry and Young 2001).

Given the above, the LEC thermal discharge does not meet the LPI decision criteria due to the occurrence of sport and commercial fish species within and moving through the thermal discharge area. In addition, some of the potentially thermally exposed areas within this section of the Missouri River contain macrohabitats that may be utilized for spawning (e.g., dike field habitats).

As the LEC thermal discharge area does not meet the decision criteria for LPI, the Guidance Manual presents requirements for additional studies to demonstrate the fish communities will not suffer appreciable harm. The LEC has undertaken the § 316(a) biological monitoring program to collect data sufficient to support water quality and biological assessments to assure the protection and propagation of a BIC of fish in the LMOR in the vicinity of the LEC thermal discharge. The current studies were designed to collect additional information relative to addressing the NPAH criteria for the fish component of the aquatic community in the vicinity of the LEC thermal discharge.

4.6 OTHER VERTEBRATE WILDLIFE

4.6.1 Category Characterization

Vertebrate wildlife other than fish includes waterfowl, turtles, and mammals (USEPA 1977). Much of the vertebrate wildlife in the LMOR such as waterfowl (e.g., herons, ducks, geese), muskrats, and raccoons will prefer the shore zone and floodplain habitats. However, the channelization of the river, including rip-rap shorelines, has significantly reduced this available habitat and has eliminated much of the shoreline vegetation suitable for wildlife (UEC 1976). Several migratory shorebird species utilize the LMOR as a migration stopover area to rest and forage for food to replenish fat reserves (Lee 2007). Lee (2007) evaluated the available food resources for migrating shorebirds on three sandbar locations (RMs 171, 177, and 213) upstream of LEC (RM 57.5). Shorebirds of primary concern thought to utilize the LMOR sandbars include the endangered piping plover and least tern species (Lee 2007).

4.6.2 Decision Criteria

The Guidance Manual defines sites of LPI for vertebrate wildlife as areas where the thermal discharge does not impact large or unique populations of wildlife or important, threatened, or endangered wildlife. The USEPA (1977) acknowledges that most sites will be considered LPI sites for this biotic category, simply because the thermal discharge will not impact large or unique populations of wildlife. Areas of exception would be cold areas (such as North Central United States) where geese and ducks could be attracted to the thermal discharge and encouraged to stay through the winter (USEPA 1977). Areas not considered sites of LPI for other vertebrate wildlife are defined as sites in which the thermal discharge might pose a danger to threatened or endangered wildlife species.

4.6.3 Other Vertebrate Wildlife Rationale

Non-fish vertebrate wildlife have minimal and intermittent exposure to the LEC's thermal discharge and are therefore not vulnerable to direct effects from the thermal discharge. With the exception of herptiles (i.e., reptiles and amphibians), vertebrate wildlife species are warm-blooded, so their body temperatures are not dependent on their surroundings, even if they are temporarily resident in waters affected by the LEC thermal discharge. Furthermore, the area of the thermal plume is limited in relation to the available foraging and habitat areas in the LMOR near the LEC. Due to this low exposure of populations and the river channelization impacts on food resources and wildlife habitat, the area of the LMOR receiving the LEC thermal discharge satisfies the decision criteria as a site of LPI.

5. RETROSPECTIVE ASSESSMENT

5.1 INTRODUCTION

As articulated in 40 CFR Part 125, Subpart H, § 125.73 (c)(1), existing thermal dischargers seeking a § 316(a) variance may support their variance request by showing that NPAH has resulted from the ongoing thermal discharge. In the Guidance Manual (USEPA 1974, 1977), demonstrations based on showing the absence of appreciable harm are termed Type I demonstrations. These demonstrations are often termed "retrospective assessments" since they rely on evaluations of exposed populations compared to those that would exist in the absence of the thermal discharge or to those that existed prior to thermal exposure to identify potential adverse changes to the ecological communities attributable to the thermal discharge.

A retrospective assessment is generally not concerned with conditions within the permit-allotted mixing zone, in which thermal effects short of acute lethality are to be expected. Retrospective assessments can examine whether the discharge has adversely changed the communities in the area exposed to the thermal plume in comparison to communities in similar habitats outside the influence of the thermal discharge. They may also compare the present ecological conditions in the area exposed to the thermal discharge to conditions existing there prior to the thermal discharge. Because ecological communities seldom remain constant, any changes detected by this type of comparison may not necessarily be attributable to the thermal discharge. However, if current and prior data from a reference area unexposed to the thermal discharge are available, that information can be used to assess whether any changes detected within the area exposed to the thermal plume are due to the discharge, or simply parallel widespread changes in the water body.

This retrospective assessment uses a variety of ecological metrics for the fish and benthic macroinvertebrate biotic categories, deemed not to be LPI, to evaluate whether the decision criteria for demonstrating NPAH identified in Section 3.3.3 are met. Some of the NPAH decision criteria can be addressed using a retrospective assessment while others are addressed via the predictive assessment presented in Section 6. The results of the retrospective and predictive assessments are used to address each of the 18 NPAH decision criteria in the Master Rationale (Section 7). The subset of NPAH decision criteria that are addressed in this retrospective assessment include:

- Presence of all trophic levels
- Presence of necessary food chain species
- Diversity
- Capability to sustain itself
- Lack of domination of pollution (heat) tolerant
- No increase in nuisance species
- Increase or decrease of indigenous species
- No decrease in threatened and/or endangered species
- Change in commercial or sport species
- Magnitude and duration of any identifiable thermal effects
- Trends in the aquatic community

A spatial analysis using data from the recent two-year biological monitoring program was used in evaluating most of these criteria. In the spatial analysis, sampled sites upstream of the influence of the thermal discharge were used as reference areas with the assumption that, other than exposure to the thermal discharge, environmental conditions would be similar to those sites sampled downstream of the discharge. The assemblages of fish and benthic macroinvertebrates in the Upstream Reference zone therefore represent the BIC or the community that would be expected to be present in the Thermally Exposed and Downstream zones in the absence of the thermal discharge. Ecological metrics including community composition, abundance/density, and diversity were compared between the Upstream Reference, Thermally Exposed, and Downstream zones to look for specific differences identified in the NPAH criteria.

In addition to the spatial analysis, a temporal analysis comparing data from available historical studies near the LEC with the recent biological monitoring program data was used to evaluate potential adverse trends in the aquatic community. The results of this temporal analysis were used to supplement the findings of the spatial analysis.

An overview of the study plan for the recent biological monitoring program and the resulting data and the available historical data sets used in the spatial and temporal analyses is presented in the following section.

5.2 LABADIE 316(a) BIOLOGICAL STUDIES

Data from current (2017-2018) studies and available historical data (1980-1985, 1997-2002) were used to evaluate whether spatial and/or temporal adverse changes have occurred, or are occurring, in areas of the LMOR exposed to the LEC thermal discharge. A brief overview of each of these studies is provided below.

5.2.1 Recent Studies

Ameren prepared and submitted a thermal discharge monitoring study plan (hereafter Study Plan) to conduct the two years of biological monitoring required by the NPDES renewal permit issued for the LEC with an effective date of August 1, 2015. The MDNR verbally approved the Study Plan with minor modifications and authorized Ameren to commence data collection beginning in February 2017 while Ameren finalized the Study Plan. The final Study Plan was approved by the MDNR on July 13, 2017. A brief summary of the Study Plan is provided below. The full Study Plan and associated addenda are presented in Appendix A. The studies of this Demonstration consist of two main components:

- Hydrothermal Modeling
- Biological Monitoring Studies

5.2.1.1 Hydrothermal modeling and site selection

A state-of-the-art three-dimensional hydrothermal model (Flow-3D) was used by Kleinfelder to model varying scenarios of river and plant operation conditions to simulate the potential spatial extent of the thermal plume. To facilitate the selection of sampling sites, a predicted water temperature difference (ΔT) of 3°F or more above ambient river temperature was used to define river areas where plume temperatures could exceed natural daily water temperature variations[2], to which resident organisms were presumed to be well adapted. The area encompassing predicted temperatures >3°F was defined as the "Thermally Exposed zone". A "Downstream zone" was defined as the river reach starting at the downstream end of the Thermally Exposed zone, and an "Upstream Reference zone" was defined as the river reach upstream of the LEC

[2]Conservatively based on a typical daily water temperature range of 1-2°F recorded at USGS gage 06935550, upstream of the LEC cooling water discharge outfall

intake and discharge outfall. In addition, a "Discharge zone" was defined as the area represented by the discharge canal and the area immediately below the canal extending to the first wing dike to be consistent with historical data collection programs. The four sampling zones were:

- An Upstream Reference zone (Zone 1) unexposed by the LEC discharge (RM 58.5 – RM 62);
- A Discharge zone (Zone 2) encompassing the area of highest potential exposure to the thermal discharge (RM 57.5 – RM 57.25);
- A Thermally Exposed zone (Zone 3) where potential effects from thermal discharge would be expected if present (RM 57.25 – RM 52); and
- A Downstream zone (Zone 4) which potentially could experience minor and transient exposure to the thermal discharge (RM 52 – RM 50).

Figure 5-1 shows the delineation of the four sampling zones.

5.2.1.2 Biological monitoring studies

Desktop and field reconnaissance surveys were conducted by Wood Environment and Infrastructure, Inc. (Wood) within each sampling zone to identify habitat types (e.g., inside bend, outside bend, dike fields), select sampling locations, and evaluate the applicability of sampling gears for each habitat type. The sampling plan was designed to ensure that multiple major habitat types were sampled in each zone to give a more complete representation of the fish and benthic macroinvertebrate assemblages.

Specific sampling sites for fish and benthic macroinvertebrate surveys were selected and stratified by habitat. A total of six habitat types (inside bend channel border, inside bend wing-dike pool, inside bend wing-dike, outside bend L-dike pool, main channel cross-over L-dike pool, and main channel cross-over L-dike bar) were selected for sampling within each zone. Sampling sites within the Thermally Exposed zone were identified first, then comparable habitat types and locations were identified in the Upstream Reference and Downstream zones. The locations selected for sample collection by habitat type are shown in the figures presented in Appendix A to Addendum 1 to the Study Plan (Appendix A). Figure 5-2 shows the location of the sampling stations in each zone.

Fish surveys were conducted by Wood using a variety of sampling gears to collect samples from the different habitat types in each of the sampling zones. The use of multiple sampling methods serves to overcome gear bias and ensure a more complete inventory of the species present in the subject receiving water body segment. Sample collection for adult and juvenile fish was conducted monthly during a two-year period (Feb. 2017- Jan. 2019). Ichthyoplankton samples were collected by Wood in inside bend wing-dike and outside bend and main channel cross-over L-dike field habitats were collected biweekly from mid-March through July and monthly during August and September during the two-year period.

Benthic macroinvertebrate and shellfish samples were collected by Wood quarterly from depositional and rock/gravel habitats in the river. Samples from depositional habitats were collected using a standard (9-inch x 9-inch) Ponar grab sampler. Samples from rock/gravel habitats were collected using H-D multi-plate samplers. In addition to noting the presence of and identifying any shellfish collected during the benthic and/or fish sample collections, Wood conducted periodic visual surveys for shellfish and mussel/clam shells to determine whether any T&E shellfish were present in the study area.

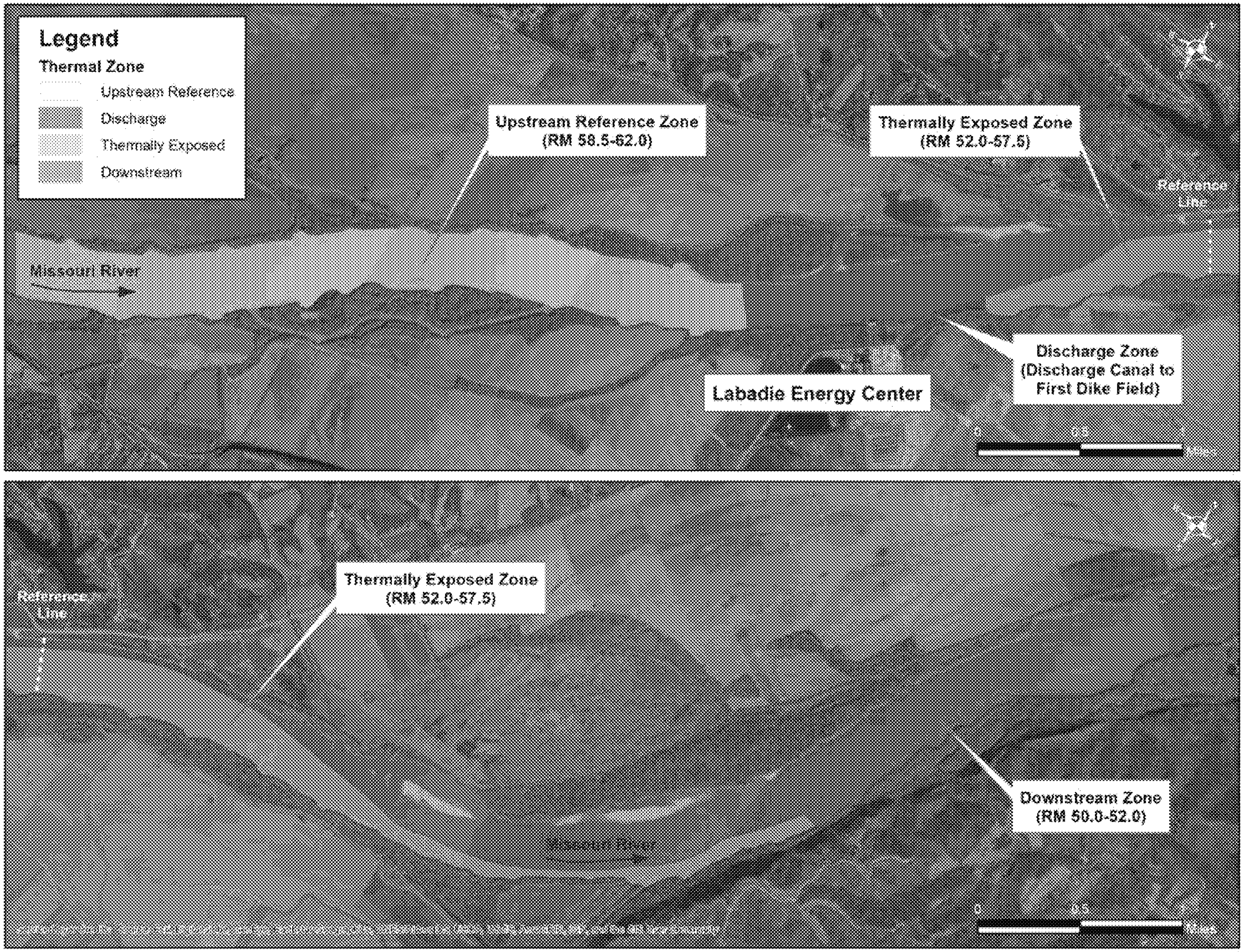


Figure 5-1 Four sampling zones identified within the study area based on thermal plume mapping for the LEC 316(a) thermal demonstration. (Color coding of the zones is continued throughout this section.)

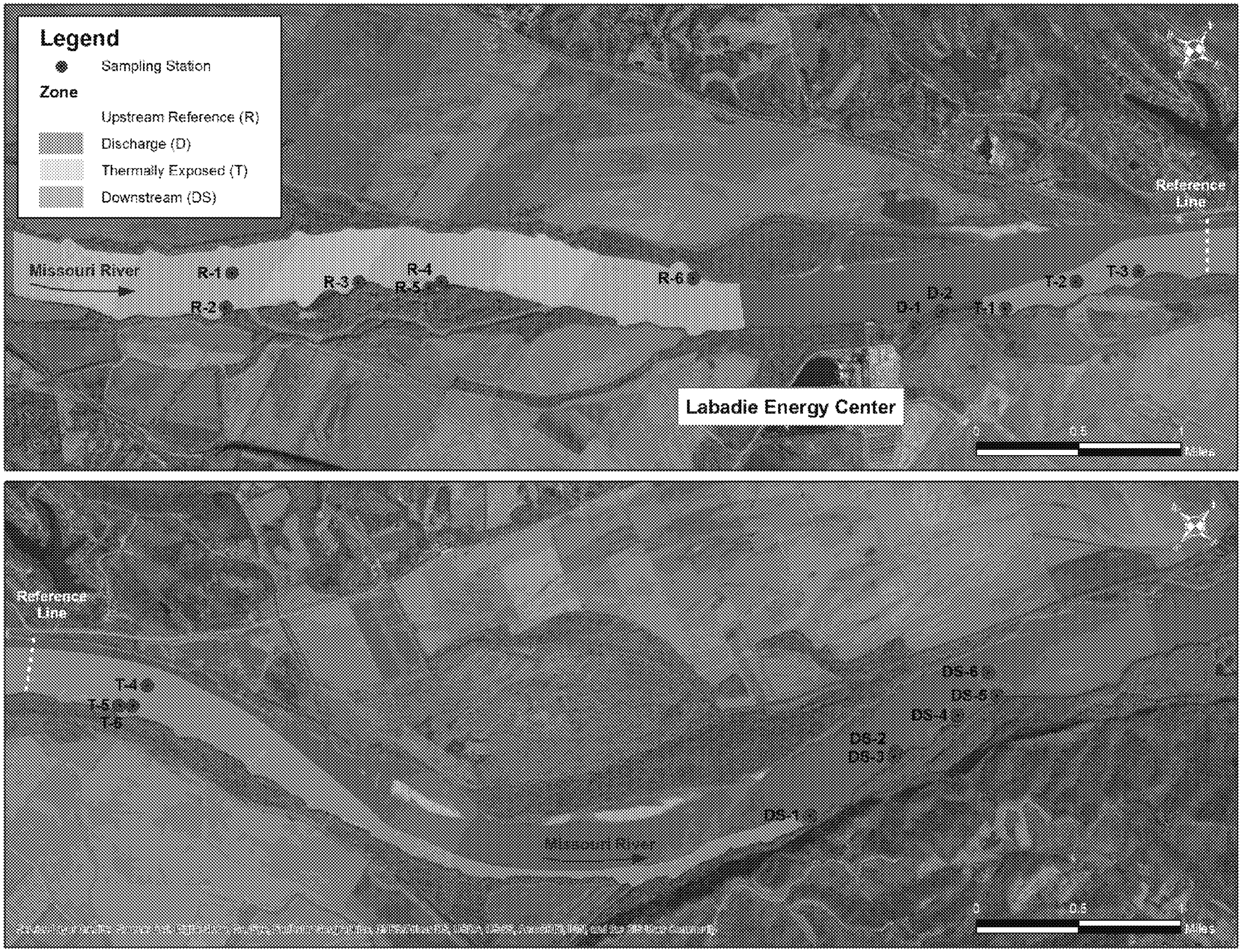


Figure 5-2 Sampling stations for the two-year biological monitoring program at the LEC, 2017-2018..

5.2.2 Historical Studies

Two sets of previous fisheries sampling data were compared to the results of the current study as part of the retrospective assessment. From 1980-1985, monthly electrofishing sampling was performed at four sites along the south shoreline of the Missouri River (Ameren 1998). Site 1 was immediately upstream of the cooling water intake; site 2 was within the discharge canal; site 3 was along the shore and outside of the dike immediately downstream of the discharge canal, and site 4 was within the wing dike downstream of site 3 (Figure 5-3). Additional monthly electrofishing surveys were performed at the same locations from 1997-2002 (Ameren 2002). An additional sampling site, Site 5 was added inshore of the dikes for the 1997-2002 survey. The data for these historical sampling programs will be compared to the recent sampling program (described in Section 5.2.1) for selected habitats.

	Reference Zone		Within Discharge		Thermally Exposed Zone
Past	Site 1		Sites 2 & 3		Site 4 & 5
Present	1-OLD		2-DIS		3-CXLD & 3-OLD

Note: OLD = outside bend L-Dike habitat; DIS = Discharge habitat; CXLD = Channel cross-over L-Dike habitat.

To facilitate the data comparison between historical and recent data sets, sample data were grouped by seasons as Winter: January-March, Spring: April-June, Summer: July-September, and Fall: October-December. Table 5-1 shows the available electrofishing data from both historical and recent studies.

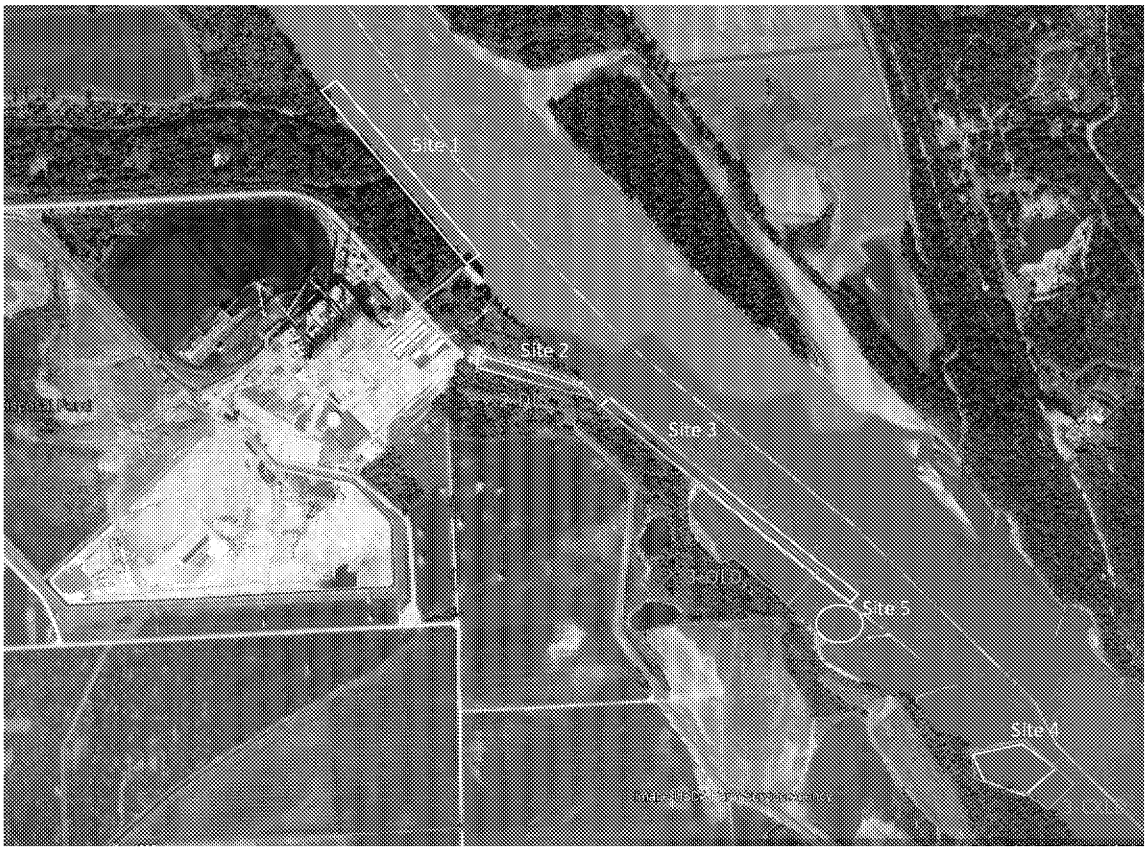


Figure 5-3 Sampling sites used in the 1980-1985 and 1997-2002 electrofishing surveys at the LEC, and corresponding site designations from the 2017-018 survey.

Table 5-1 Number of electrofishing collections conducted in each zone and habitat during the LEC fisheries sampling in 1980-1985, 1997-2002, and 2017-2018. Highlighted cells indicate groups of collections for which temporal questions T1-T4 were examined.

Zone	Habitat	Winter			Spring			Summer			Fall		
		1980-85	1997-02	2017-18	1980-85	1997-02	2017-18	1980-85	1997-02	2017-18	1980-85	1997-02	2017-18
1	CXLD	0	0	6	0	0	6	0	0	6	0	0	6
	IWD	0	0	6	0	0	6	0	0	6	0	0	5
	OLD	1	6	6	5	6	6	6	6	6	7	5	6
2	DIS	1	6	6	5	6	6	6	6	6	7	5	6
3	CXLD	1	6	6	5	6	6	6	6	6	7	5	6
	IWD	0	0	6	0	0	6	0	0	6	0	0	6
	OLD	0	6	6	0	6	6	0	6	6	0	5	6
4	CXLD	0	0	6	0	0	6	0	0	6	0	0	6
	IWD	0	0	6	0	0	6	0	0	6	0	0	6
	OLD	0	0	6	0	0	6	0	0	6	0	0	6

5.3 ENVIRONMENTAL AND OPERATIONAL CONDITIONS CONTEXT

Prior to the analysis of the biological data, environmental and the LEC operation information was summarized to determine if the study years can be considered representative of typical conditions. The results of this summary are presented below.

5.3.1 River temperature and flow

Mean daily Missouri River discharge flows measured at the USGS gage #06935550 at Labadie were generally above historical average flows (measured at the USGS Hermann gage, #06934500) for much of the period from April through August during the first year of study and from September through January during the second year (Figure 5-4). In 2017, flows during the April to August period ranged up to 2.5 times historical average flows and remained well below historical maximums except for May when flows reached the historical maximum of 500,000 cfs. In 2018, flows during the September through January period ranged up to approximately 1.5 times the historical average flows and remained well below historical maximums except for two peaks in early September and October which reached the historical maximum values.

Mean daily water temperatures (measured at the Labadie gage) were close to historical average values (measured at the Hermann gage) throughout the two-year study period 2017-2108 (Figure 5-5). Water temperatures in June and July 2017 were slightly warmer than average, while they were around average values in those months during 2018.

Continuous temperature monitoring data from the surface and bottom recorded by Wood at each sampling station in Discharge, Thermally Exposed, and Downstream zones for the 2017 and 2018 study years were compared to ambient river water temperatures recorded at the Labadie gage (Figure 5-6 through Figure 5-9). For all stations there was little difference between surface and bottom measured temperatures. As expected, Discharge zone water temperatures were well above ambient temperatures throughout each year though temperatures recorded at the Discharge zone station in the river (Dis 2) were typically several degrees cooler than those recorded in the discharge canal (Dis 1). Water temperatures at all other stations were close to or only a few degrees above the recorded ambient river water temperature.

River flow was quite variable during the 2017-2018 study period but with one exception, remained within the observed historical variability. River water temperatures were considered representative of typical conditions as they were close to historical averages. Field measured water temperatures show that the thermal discharge is rapidly attenuated by mixing with the mainstem river by the first downstream dike field.

5.3.2 Plant generation and discharge flow

The LEC operated normally during the first year of study and did not experience periods of outage or non-operation during the summer months. The LEC mean annual capacity factors for 2017 and 2018 were similar to the five-year mean capacity factor of 73 percent (Table 5-2). During the summer months of July and August, the LEC capacity factors for 2017 and 2018 were similar to the mean values for those months during the previous five-year operating period (Table 5-2).

The LEC thermal discharge flows were below historical average discharge flows in March, April, June, late July/early August, and September in 2017 and in late May and September through December in 2018 (Figure 5-10). Plant discharge flows approximated the historical average from late June through late July in both study years. The LEC thermal discharge flows for each of the study years were within historical ranges and are considered representative of typical conditions, particularly during the summer period.

Mean daily discharge temperatures for the LEC in 2017 were below historical mean values for periods from March through early June and again in August and September and at or above historical mean values for periods in June, July, and late September (Figure 5-11). In 2018, mean daily discharge temperatures for the LEC were above historical mean values in May and June and below the historical mean value in July. All LEC mean daily discharge temperatures were within historical ranges and are considered representative of typical conditions, particularly during the summer period.

Table 5-2 The LEC Capacity factors for 2014 through 2018.

Year	Percentage of Maximum Generation												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	86	88	76	49	48	73	87	82	55	64	61	77	71
2015	89	80	77	60	60	81	82	71	76	72	75	71	75
2016	78	75	52	58	44	72	77	82	67	70	77	76	69
2017	80	75	57	65	76	74	83	80	71	79	81	78	75
2018	84	80	73	77	75	75	84	81	62	64	64	62	73
Mean	83	80	67	62	61	75	83	79	66	70	72	73	73

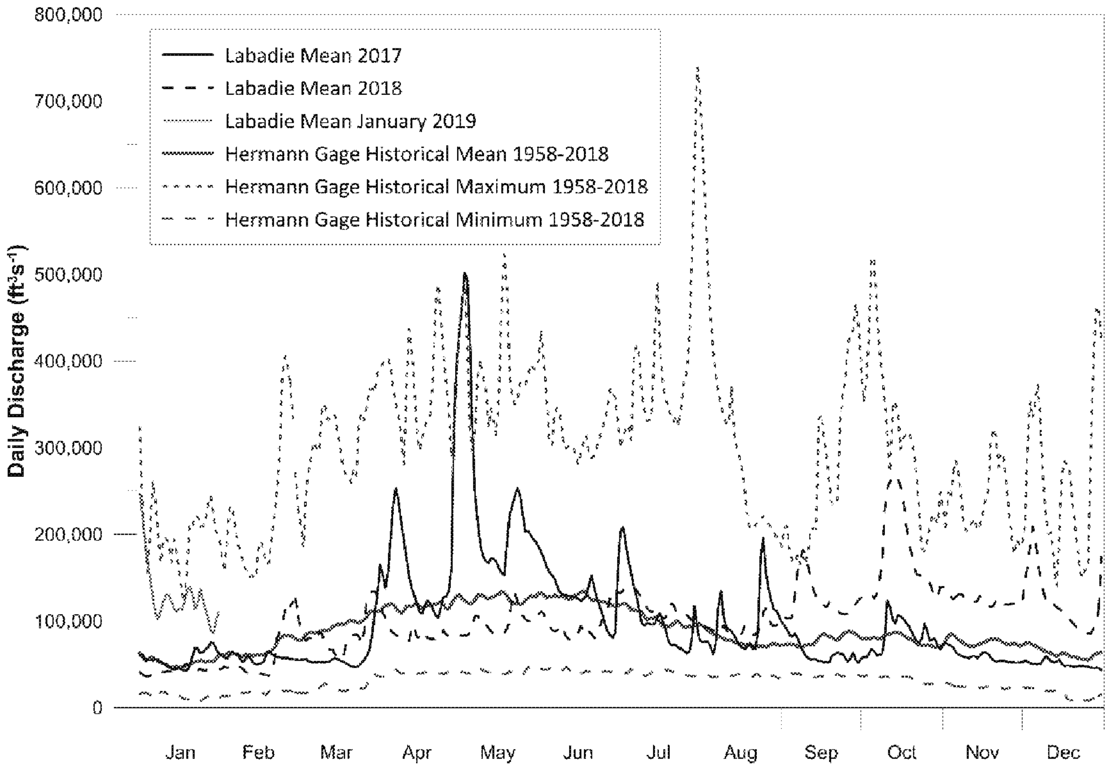


Figure 5-4 Historical and 2017- January 2019 daily mean Missouri River discharge flows measured at the Hermann and Labadie gages, respectively.

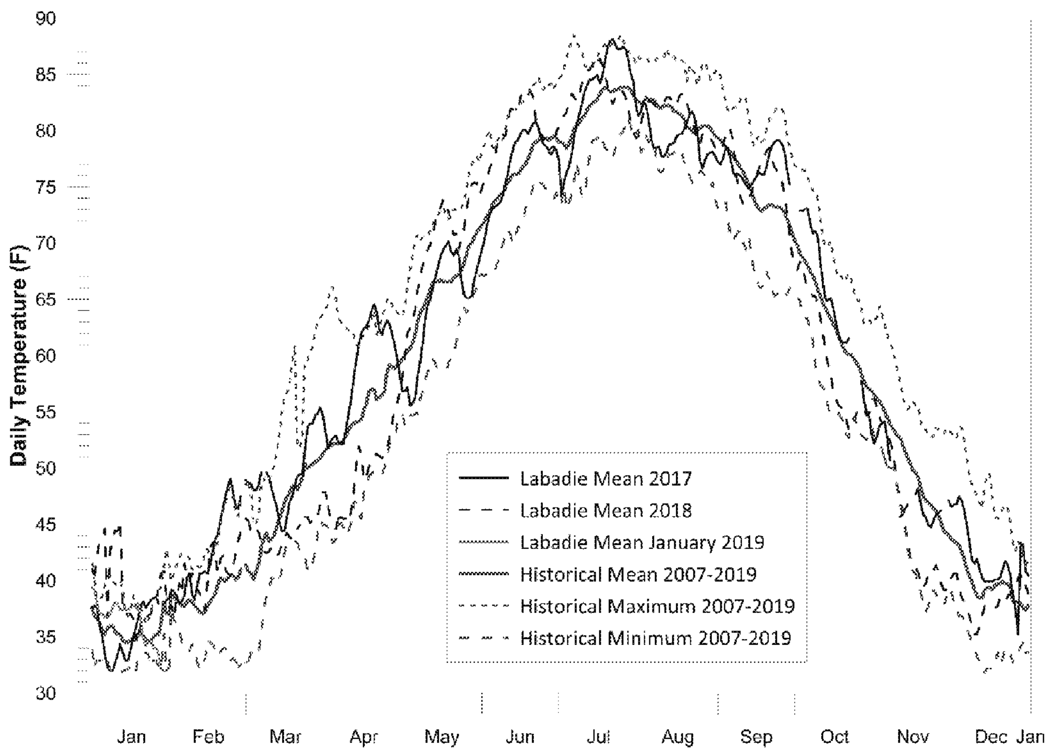


Figure 5-5 Historical and 2017- January 2019 daily mean Missouri River water temperature measured at the Hermann and Labadie gages, respectively.

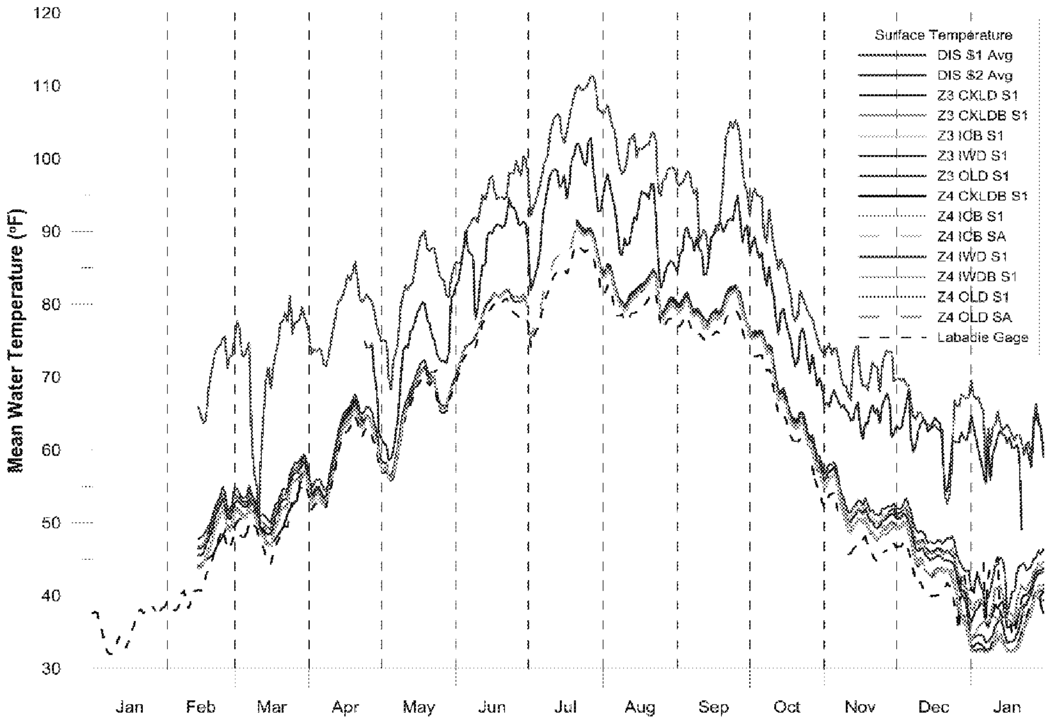


Figure 5-6 Surface-measured continuous monitoring water temperature data from each sampled site compared to Labadie gage ambient temperatures for 2017.

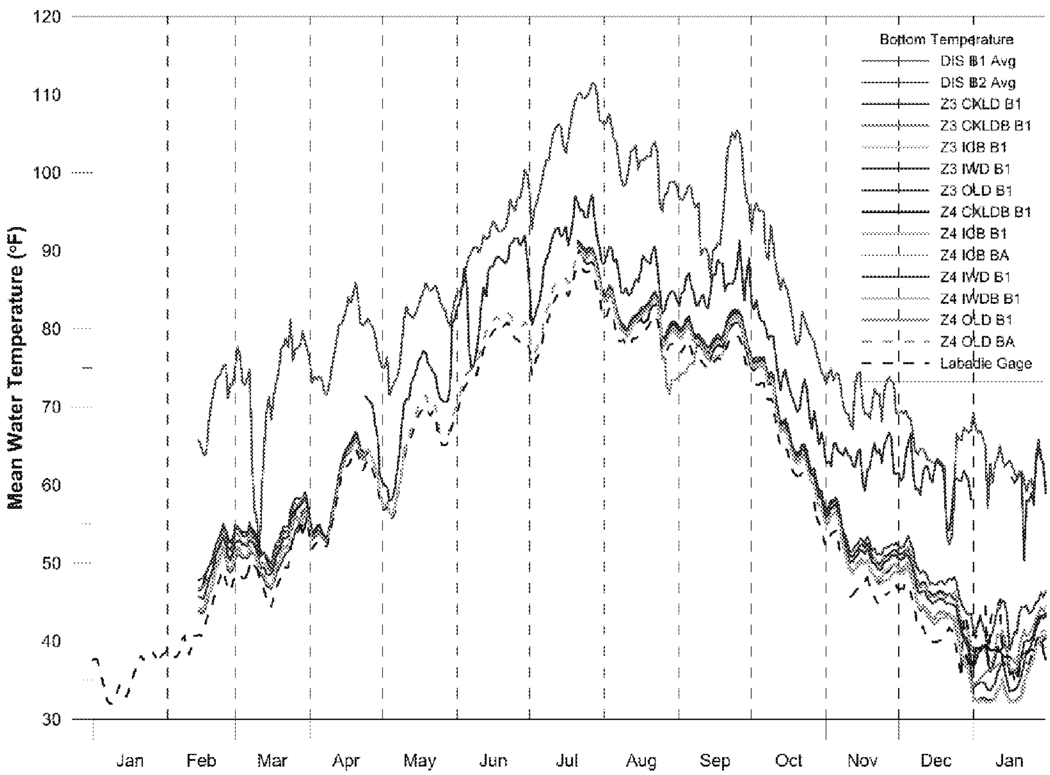


Figure 5-7 Bottom-measured continuous monitoring water temperature data from each sampled site compared to Labadie gage ambient temperatures for 2017.

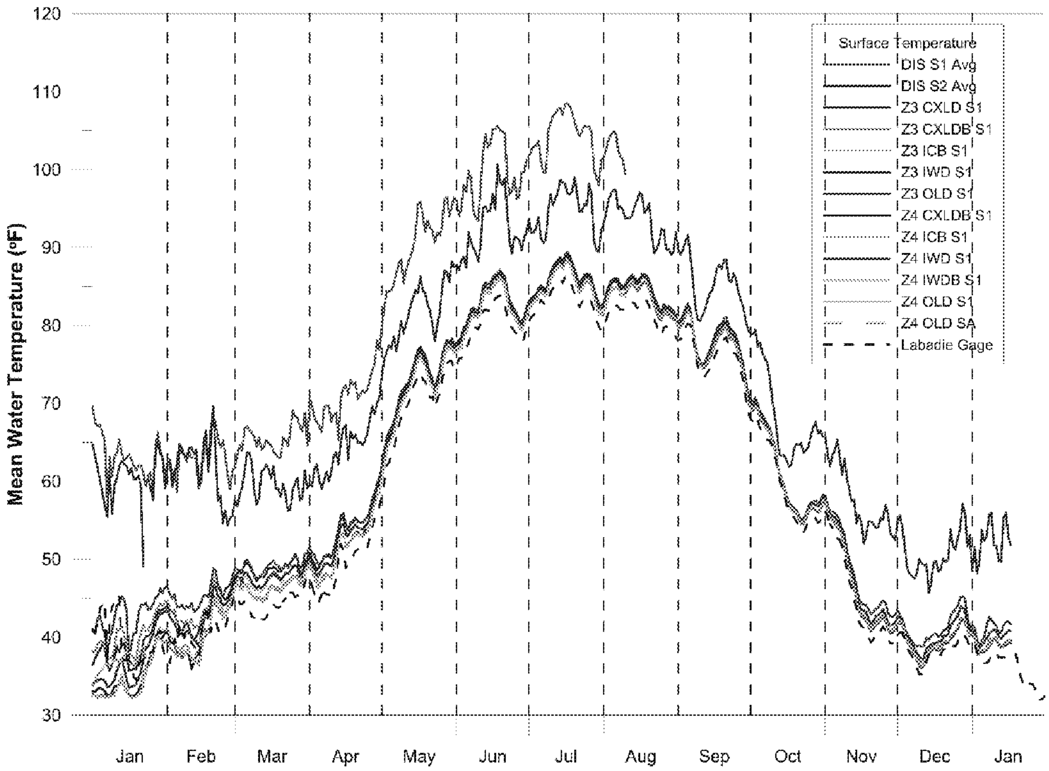


Figure 5-8 Surface measured continuous monitoring water temperature data from each sampled site compared to Labadie gage ambient temperatures for 2018.

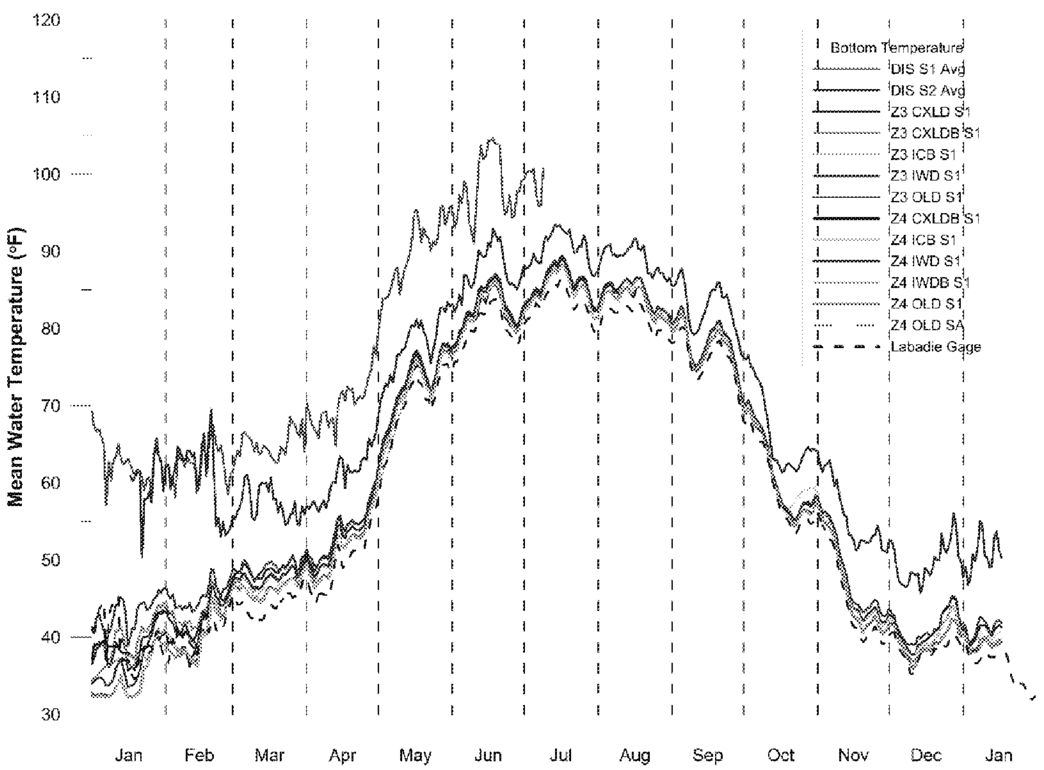


Figure 5-9 Bottom measured continuous monitoring water temperature data from each sampled site compared to Labadie gage ambient temperatures for 2017.

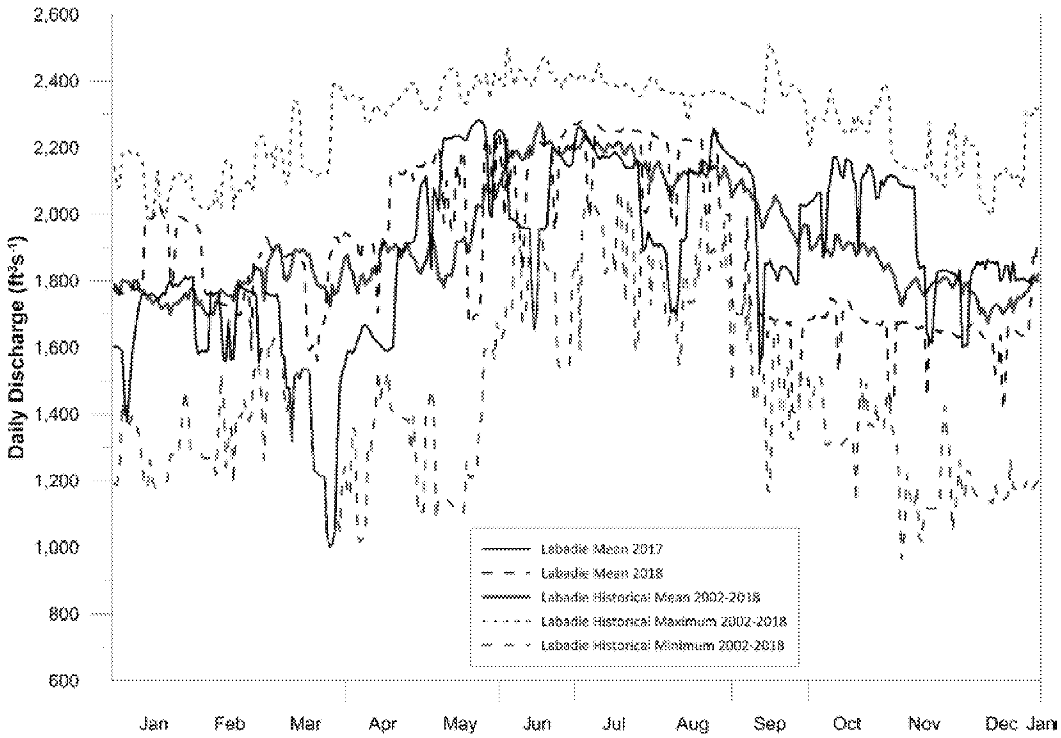


Figure 5-10 Historical and 2017-2018 mean daily thermal discharge flows for the LEC.

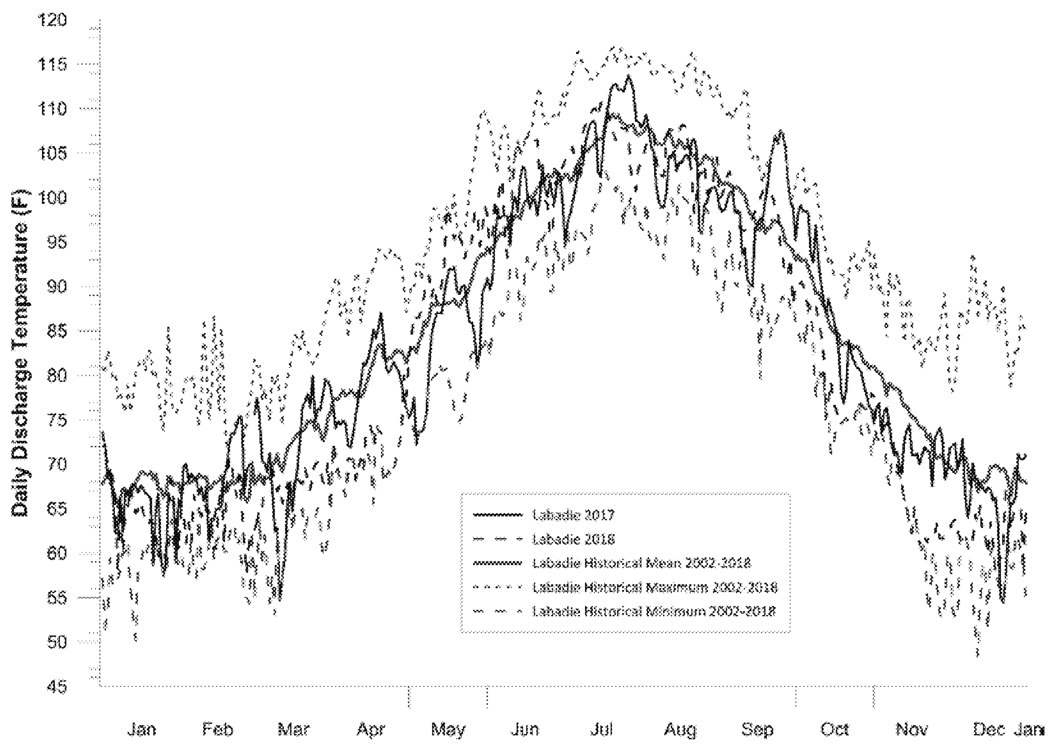


Figure 5-11 Historical and 2017-2018 mean daily discharge temperatures for the LEC.

5.4 SPATIAL ANALYSIS

5.4.1 Fish

The fish assemblage in the LMOR in the vicinity of the LEC was described by the two-year sampling program using bag seines, electrofishing, hoop nets, and Missouri trawls, in selected habitats in the four sampling zones: the Upstream Reference zone, Discharge zone within and immediately downstream of the discharge canal, the Thermally Exposed zone where the excess temperatures are > 3°F, and the Downstream zone. The fish assemblages in all zones were robust, containing many different species, and of a diverse number of ecological and human-use types. Overall, a total of 70 species and two different hybrids were identified.

The total number of fish collected (all gears and both study years combined) from the Upstream Reference, Thermally Exposed, and Downstream zones were similar, at 9,150, 7,104, and 8,063 fish respectively (Table 5-3). The Discharge zone was sampled only with electrofishing gear, which produced a total of 948 fish collected.

Dominant fish species were also similar across zones, with red shiner being ranked first in all zones. Other prominent species found abundantly in all zones, or all zones but the Discharge zone, were gizzard shad, channel shiner, sicklefin chub, shoal chub, and bullhead minnow. Summary tables for all fish data are presented in Appendix B Section B.1.

5.4.1.1 Overall Abundance

The fisheries sampling data collected by Wood in 2017-2018 exhibited differences in "densities" i.e. mean catch from each of the sampling gears standardized to the target level of effort (duration of sampling or area sampled) in terms of both numerical abundance and total fish biomass. The results are summarized for the summer in Figure 5-12 and winter seasons in Figure 5-13. Data from bag seine and electrofishing collections during the summer showed similar densities between the Upstream Reference and Thermally Exposed zones while other gears indicated lower densities in the Thermally Exposed zone. In summer electrofishing samples, fish biomass was greater in the Thermally Exposed zone compared to the Upstream Reference zone. During winter electrofishing sampling, the Discharge zone contained higher densities than the other zones, indicating a degree of attraction to the heated discharge. Spring and fall sampling similarly did not show a consistent pattern of reduced abundance in either the Thermal or Downstream zones (Full tabular results are presented in Appendix B). Overall, there was not a consistent pattern of lower abundance in the Thermally Exposed and Downstream Zones than in the Upstream Reference zone demonstrating no adverse effect of the LEC's thermal discharge on overall fish abundance.

Table 5-3 Species composition in each zone from fisheries sampling programs near the LEC during 2017-2018.

	Upstream Zone			Discharge Zone			Thermally Exposed Zone			Downstream Zone		
Rank	Taxon	Number	Fraction	Taxon	Number	Fraction	Taxon	Number	Fraction	Taxon	Number	Fraction
1	Red shiner	3,056	0.334	Red shiner	330	0.348	Red shiner	1,291	0.182	Red shiner	1,824	0.226
2	Channel shiner	1,287	0.141	Blue catfish	154	0.162	Emerald shiner	914	0.129	Channel shiner	1,055	0.131
3	Sicklefin chub	568	0.062	River carpsucker	67	0.071	Gizzard shad	757	0.107	Gizzard shad	980	0.122
4	Shoal chub	559	0.061	Emerald shiner	59	0.062	Channel shiner	743	0.105	Emerald shiner	636	0.079
5	Gizzard shad	557	0.061	Gizzard shad	56	0.059	Sicklefin chub	627	0.088	Shoal chub	631	0.078
6	Emerald shiner	495	0.054	Freshwater drum	46	0.049	Shoal chub	607	0.085	Sicklefin chub	472	0.059
7	Freshwater drum	487	0.053	Longnose gar	35	0.037	Freshwater drum	371	0.052	Bullhead minnow	286	0.035
8	Blue catfish	350	0.038	Shortnose gar	31	0.033	Blue catfish	282	0.040	Freshwater drum	275	0.034
9	Channel catfish	279	0.030	Flathead catfish	22	0.023	Channel catfish	242	0.034	Blue catfish	270	0.033
10	Bullhead minnow	255	0.028	Common carp	20	0.021	Silver carp	167	0.024	Channel catfish	256	0.032
11	Sand shiner	205	0.022	Channel catfish	19	0.020	Bullhead minnow	104	0.015	Silver carp	153	0.019
12	Silver carp	155	0.017	Smallmouth buffalo	19	0.020	River carpsucker	100	0.014	Goldeye	141	0.017
13	Goldeye	115	0.013	Silver carp	13	0.014	Goldeye	90	0.013	Blacktail chubs	117	0.015
14	River carpsucker	74	0.008	Striped bass x white bass	12	0.013	Longnose gar	86	0.012	Mosquitofish	105	0.013
15	Longnose gar	66	0.007	Goldeye	11	0.012	Shortnose gar	86	0.012	Sand shiner	85	0.011
>15	56 additional taxa	642	0.072	22 additional taxa	54	0.057	56 additional taxa	637	0.090	53 additional taxa	777	0.096
	Total	9,150	1.000	Total	948	1.000	Total	7,104	1.000	Total	8,063	1.000

5.4.1.2 Capability to Sustain Itself

Length-frequency distribution data shows that multiple size classes and year classes of fish are present in all sampled zones. Figure 5-14 shows example length-frequency distributions for selected large-bodied fishes which would exhibit enough range in lengths to demonstrate the presence of multiple year-classes: gizzard shad, blue catfish, silver carp, channel catfish, freshwater drum, and the sucker family. The distribution of length classes of fish was similar among the Upstream Reference, Thermally Exposed, and Downstream zone, but skewed toward larger fish in the Discharge zone. The presence of multiple size and year classes of fish and the absence of any difference in the length-frequency distributions between Upstream Reference, Thermally Exposed, and Downstream zones indicate that the LEC thermal discharge is not preventing the fish exposed to the discharge from reproducing and sustaining themselves.

5.4.1.3 Community Characteristics

Diversity

Diversity of the community was described based on Hill numbers (Hill 1973), which provide a profile of the community diversity along a spectrum of sensitivity to abundance. Hill numbers are currently the dominant paradigm for describing diversity of ecological communities (Chao et al 2010). The diversity profile includes three special cases, which are the equivalent of three of the previously most commonly used diversity metrics. At the low end of the sensitivity spectrum, ($q = 0$) the Hill number is completely insensitive to abundance, and the Hill number (${}^{0}D$) is equivalent to simple species richness. At $q = 1$, the value of the Hill number is equal to the exponential of the Shannon index (${}^{1}D = e^{H'}$) and represents the number of equally abundant species that would constitute a community with the measured level of diversity. At $q = 2$, the Hill number represents the number of abundant species in the community and is the numerical equivalent of the inverse of the Simpson concentration. At higher values of q, the Hill numbers are increasingly sensitive to abundance so that rare species become less influential and highly abundant species dominate the value of the metric. Because fish vary greatly in individual size (biomass) and therefore dominant species in terms of numerical abundance could be far less significant in terms of community biomass, the profiles were calculated both for numerical abundance and for biomass.

The diversity profiles varied among gear and zones but did not indicate lower diversity in either the Thermally Exposed or Downstream zones compared to the Upstream Reference zone (Figure 5-15). Diversity profiles based on biomass typically declined more steeply as sensitivity to abundance (q) increased than did profiles based on numerical abundance, indicating that biomass is more concentrated in a few species, such as gizzard shad, blue catfish, flathead catfish, bighead carp, than is numerical abundance. There was no observed effect of the LEC's thermal discharge on fish diversity.

Dominance

Although there are many species of fish in the LEC vicinity, the community is dominated by a relatively small number of species. In terms of numbers, the most abundant species comprised 18 percent (Thermally Exposed zone) to 35 percent (Discharge zone) of the total catch, with the top two species contributing 31 to 51 percent, the top 5 species 61 to 70 percent, and the top 10 species 83 to 86 percent across all zones (Figure 5-16). The most abundant species across all zones were red shiner (26 percent), channel shiner (12 percent), gizzard shad (9 percent), emerald shiner (8 percent), and shoal chub (7 percent) (Table 5-4). All of the five most abundant species except gizzard shad are small-bodied forage species.

Community biomass was also dominated by a few species in all zones, however the discharge zone, which was sampled only by electrofishing, was much more dominated by a single species (Table 5-4). The Upstream Reference zone and the Thermally Exposed zone exhibited nearly identical dominance curves (Figure 5-16). The top five species in terms of biomass were blue catfish (25 percent), common carp (12 percent), smallmouth buffalo (11 percent), silver carp (9 percent), and river carpsucker (7 percent). Except for blue catfish and smallmouth buffalo, the dominant species were I in the rough fish category.

The dominant species were very similar among all four sampling zones. For numerical dominance, red shiner and gizzard shad were in the top five in abundance in all four zones, and emerald shiner and channel shiner in three zones. For biomass, common carp, smallmouth buffalo, and blue catfish were in the top five in biomass in all four zones, and silver carp and river carpsucker in three of the four zones. There was no evidence of an effect of the LEC's thermal discharge on the dominant fish species in the area.

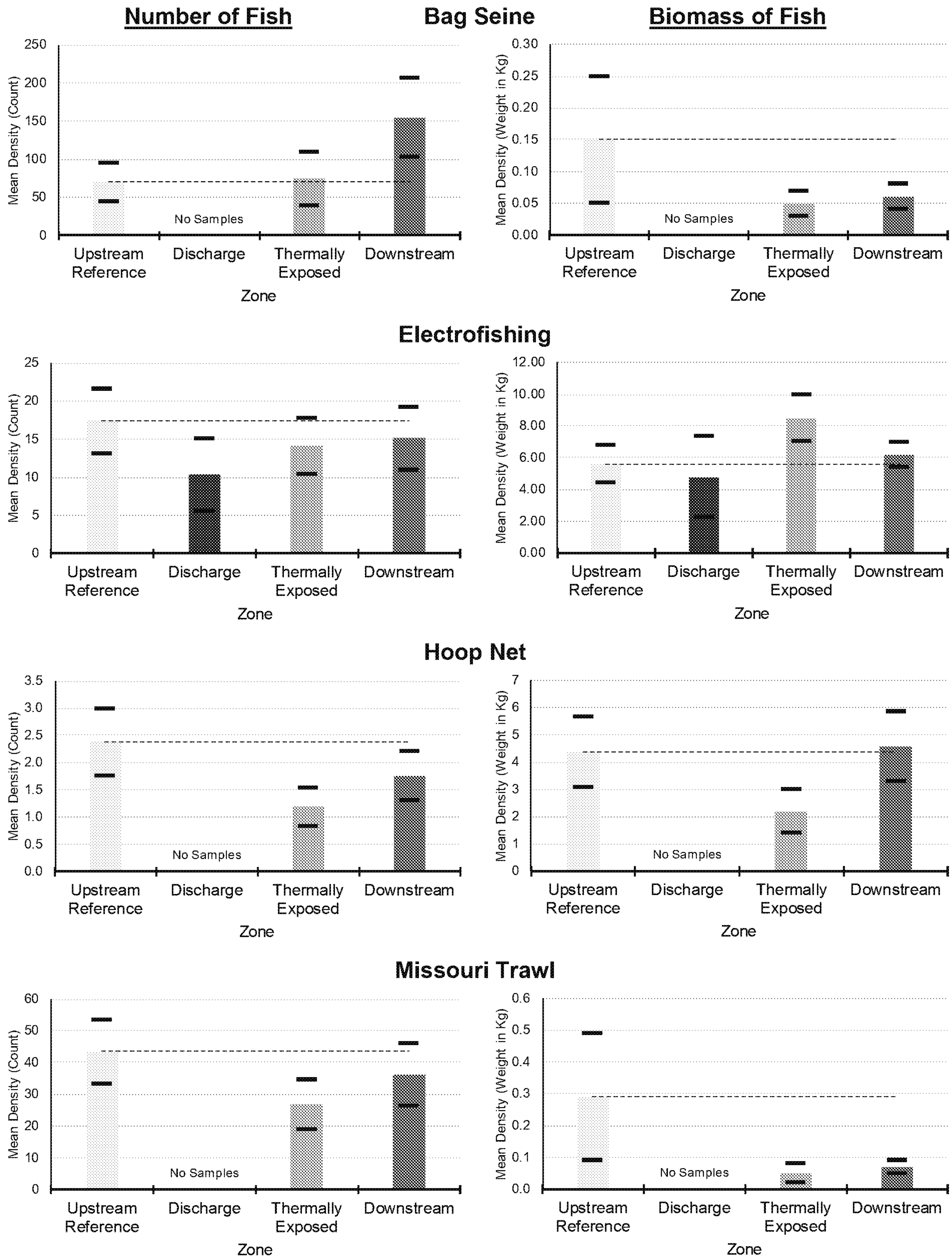


Figure 5-12 Summer mean density in fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Black bars indicate +/- 1 standard error from mean.

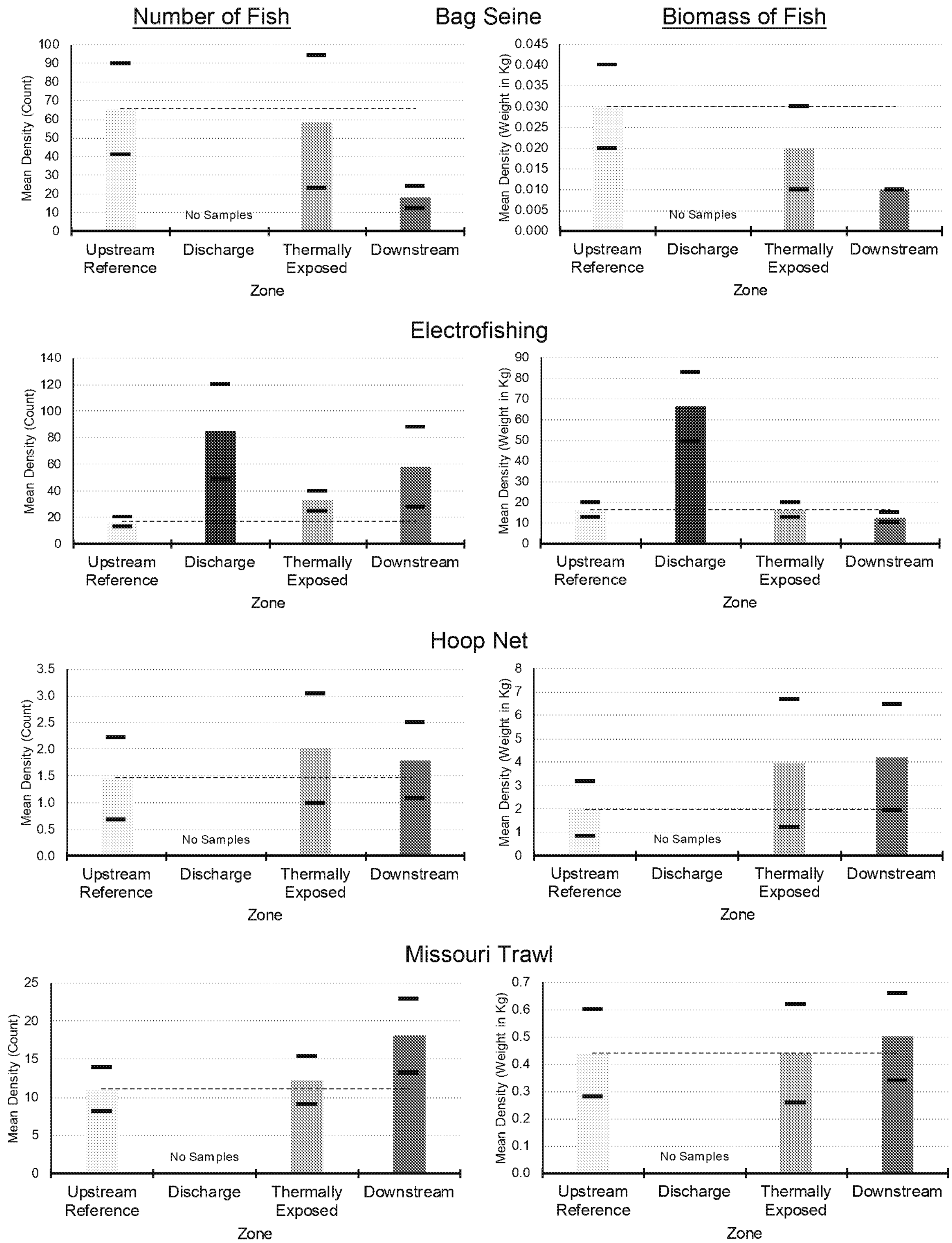


Figure 5-13 Winter mean density of fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Black bars indicate +/- 1 standard error from mean.

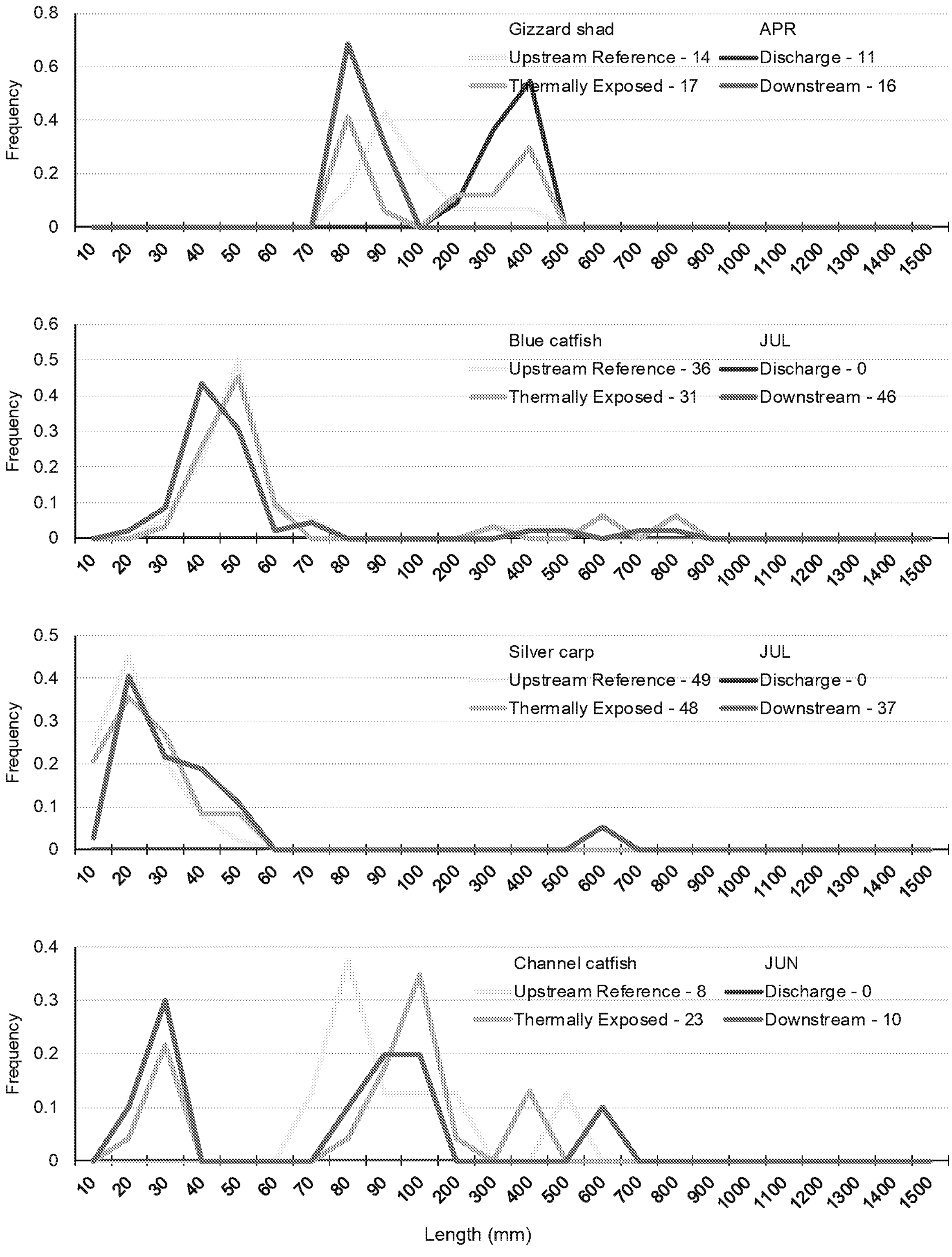


Figure 5-14 Length frequency of selected fish taxa collected in the vicinity of the LEC in 2017-2018 by all sampling gears across all seasons.

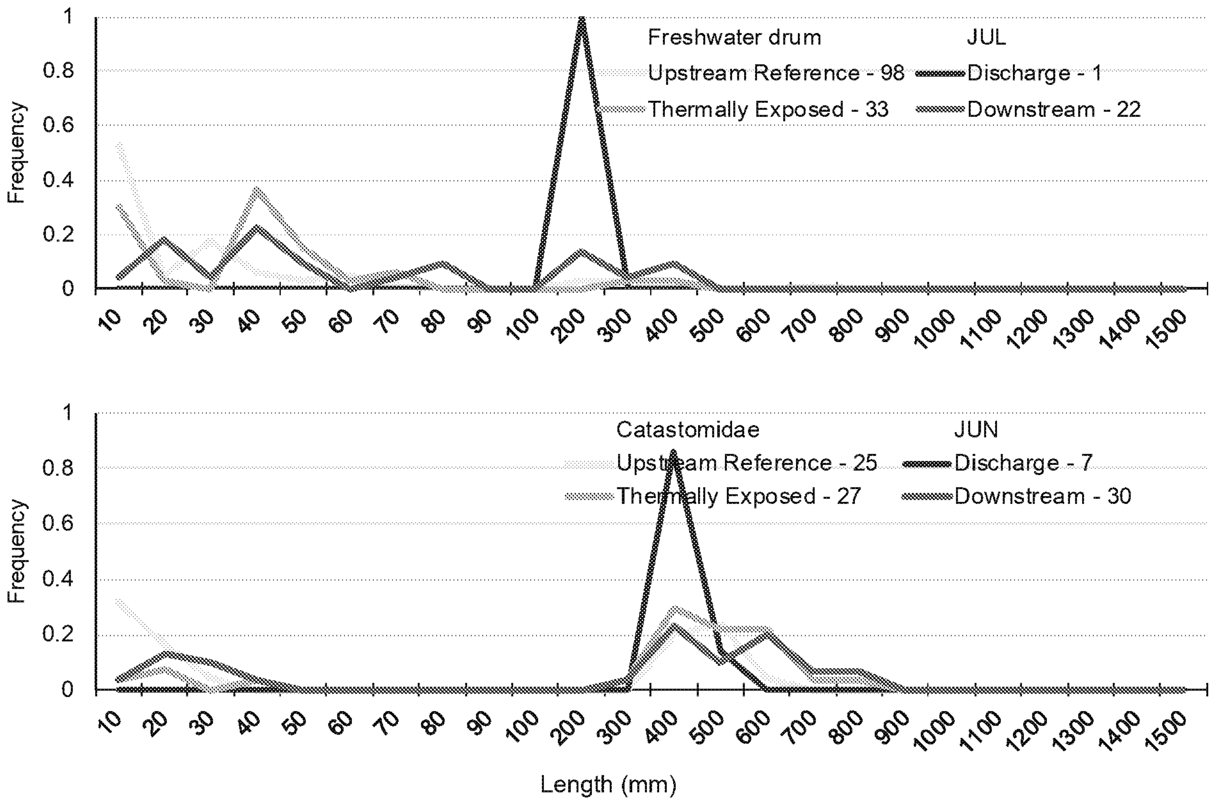


Figure 5-14 Continued.

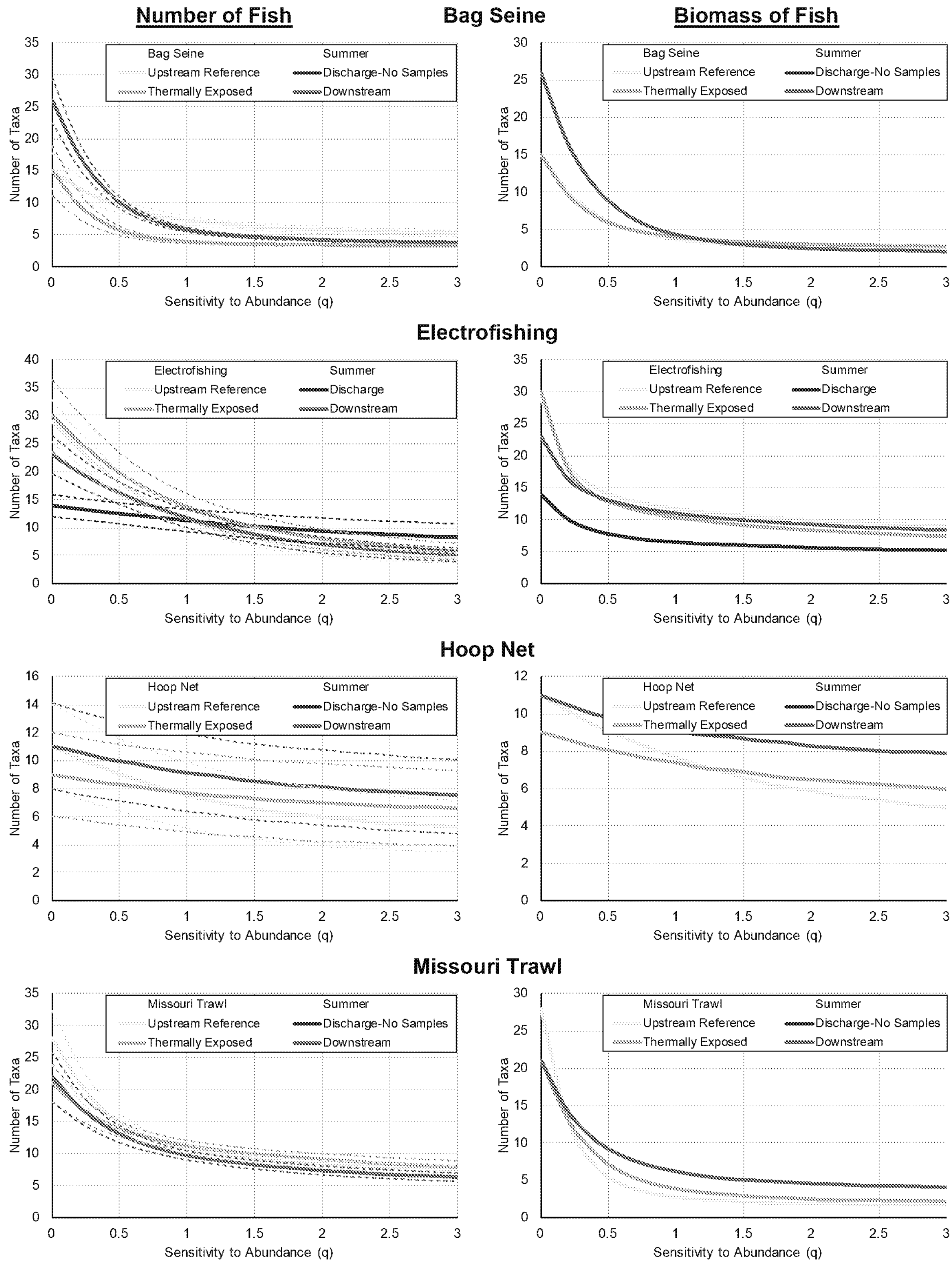
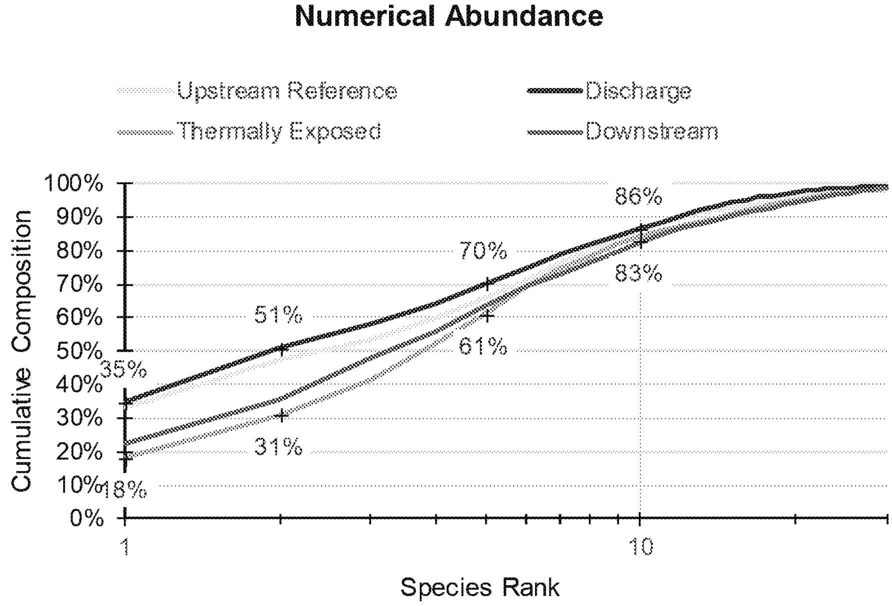


Figure 5-15 Summer diversity profiles of fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Dashed lines for numerical profiles indicate +/- 1 standard deviation around estimate.



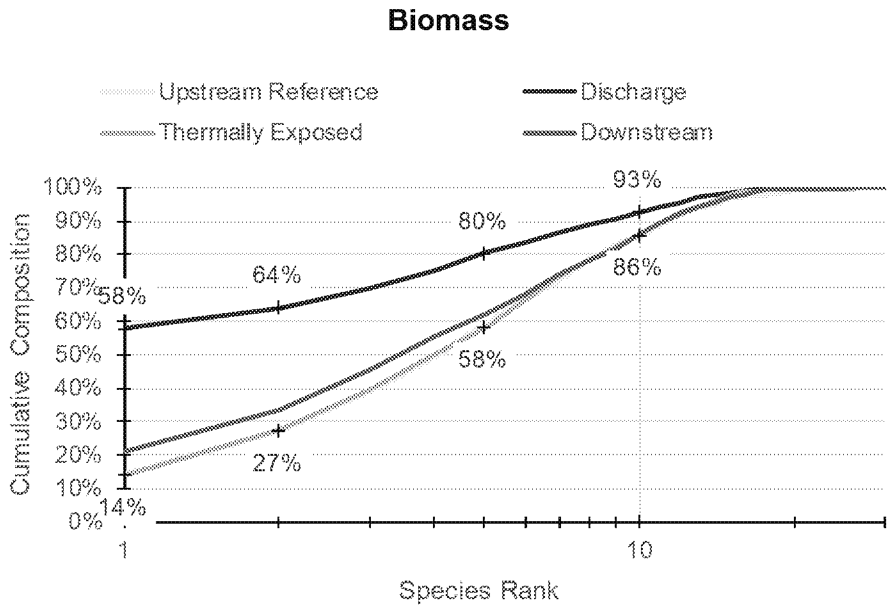


Figure 5-16 Dominance of the fish community in the LEC vicinity based on all sampling gears combined over all seasons, 2017-2018. Top figure is based on numerical abundance and bottom on biomass.

Table 5-4 Dominant fish species collected in the vicinity of the LEC in 2017-2018 from all gears and seasons, in terms of numerical abundance and biomass.

		Upstream Reference		Discharge		Thermally Exposed		Downstream	
Basis	**Rank**	**Species**	**%**	**Species**	**%**	**Species**	**%**	**Species**	**%**
Numbers	1	Red shiner	33%	Red shiner	35%	Red shiner	18%	Red shiner	23%
	2	Channel shiner	14%	Blue catfish	16%	Emerald shiner	13%	Channel shiner	13%
	3	Sicklefin chub	6%	River carpsucker	7%	Gizzard shad	11%	Gizzard shad	12%
	4	Shoal chub	6%	Emerald shiner	6%	Channel shiner	10%	Emerald shiner	8%
	5	Gizzard shad	6%	Gizzard shad	6%	Sicklefin chub	9%	Shoal chub	8%
	Total		66%		70%		61%		64%
Biomass	1	Common carp	14%	Blue catfish	58%	Smallmouth buffalo	14%	Blue catfish	21%
	2	Smallmouth buffalo	13%	Common carp	6%	Common carp	13%	Common carp	12%
	3	Blue catfish	12%	River carpsucker	6%	Silver carp	12%	Silver carp	12%
	4	Silver carp	10%	Flathead catfish	5%	Blue catfish	11%	Smallmouth buffalo	10%
	5	Grass carp	10%	Smallmouth buffalo	5%	River carpsucker	8%	River carpsucker	7%
	Total		59%		80%		58%		62%

Presence of all Trophic Levels

The fish community was separated into trophic categories based on Pearson et al. (2011), which included detritivores, planktivores, herbivores, omnivores, insectivores, carnivores, top predators, and combinations of these categories for species not well-categorized into a single group (Table 5-5). Although the division of the community into the trophic categories varied somewhat whether numbers or biomass was the basis for categorization, the Upstream Reference, Thermally Exposed, and Downstream zones differed little among each other and showed the presence of all trophic levels in each zone (Figure 5-17). The Discharge zone appeared to have an elevated frequency of carnivore and top predator categories compared to the other zones. Hence, the LEC's thermal discharge did not prevent the presence of all appropriate trophic levels.

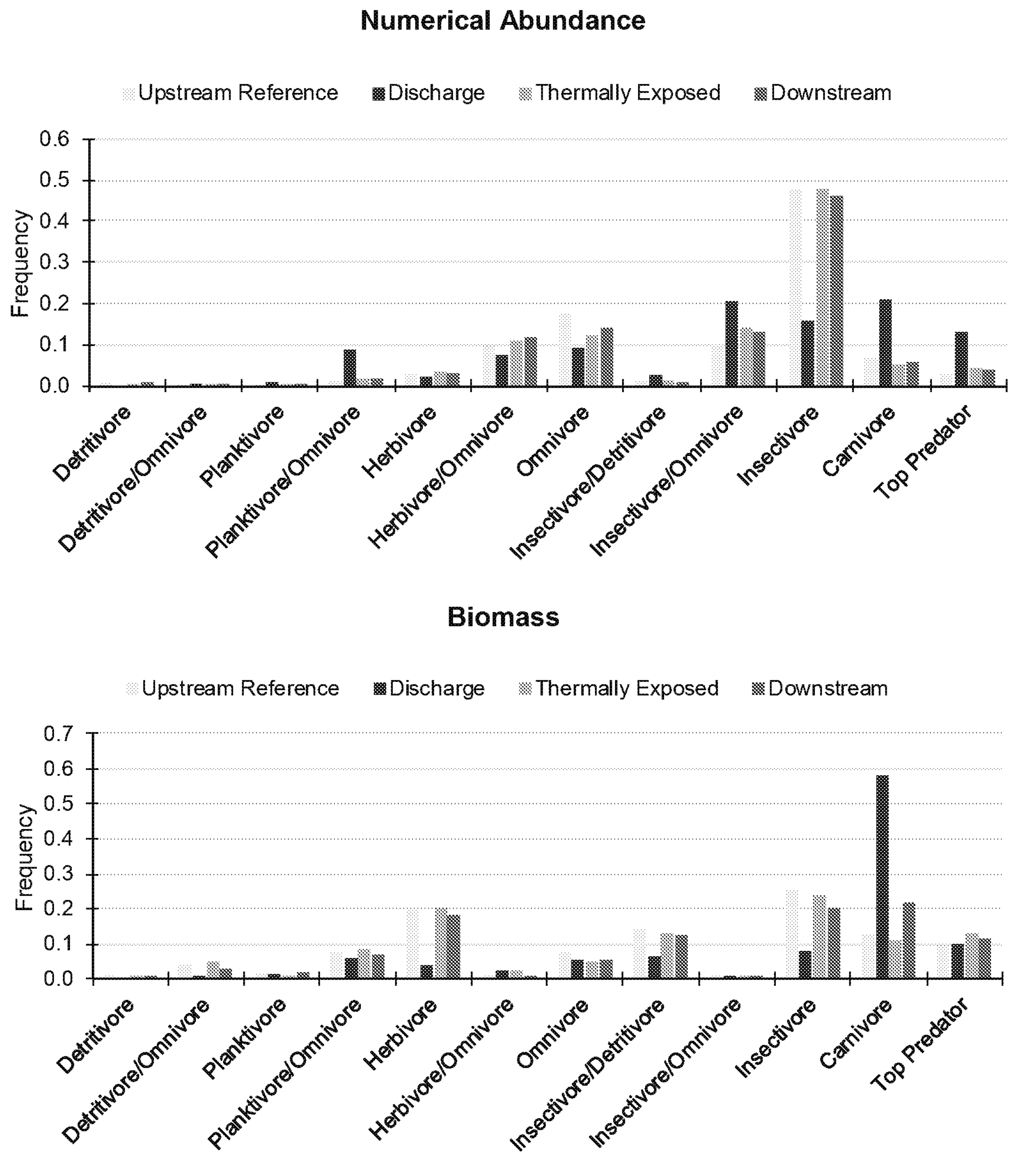


Figure 5-17 Trophic categories of the fish community sampled in the vicinity of the LEC in 2017-2018 based on all sampling gears over all seasons.

Table 5-5 Classification of LMOR fishes collected at LEC 2017-2018 into trophic guilds based on Pearson et al. 2011.

Carnivore	**Herbivore**	**Invertivore**	**Invertivore**	**Top Piscivore**
Rock bass	Stonerollers	Lake sturgeon	Bigeye shiner	Smallmouth bass
Spotted bass	Central stoneroller	Sturgeon - Scaphirhynchus	Ghost shiner	Largemouth bass
White bass	Grass carp	Pallid sturgeon	Rosyface shiner	Striped bass
Chestnut lamprey	Plains minnow	Shovelnose x Pallid	Silverband shiner	Striped bass x white bass
Blue catfish	Silver carp	Shovelnose sturgeon	Sand shiner	Pikeperch
	Minnow Family group 2	Brook silverside	Channel shiner	Sauger
Detritivore	Silver lamprey	Banded killifish	Suckermouth minnow	Sauger x Walleye
Bluntnose minnow		Plains killifish	Creek chub	Walleye
	Omnivore	Quillback carpsucker	Mooneyes	Gar Family
Detritivore-Omnivore	American eel	White sucker	Goldeye	Longnose gar
Bigmouth buffalo	Bullhead minnow	Blue sucker	Mooneye	Shortnose gar
Black buffalo	White crappie	Smallmouth buffalo	Green sunfish	Flathead catfish
Goldfish	Freshwater drum	Spotted sucker	Orangespotted sunfish	
Fathead minnow	Channel catfish	Sucker - Redhorses	Bluegill	
		Silver redhorse	Longear sunfish	
Herbivore-Omnivore	**Planktivore-Omnivore**	Golden redhorse	Black crappie	
Gizzard shad	River carpsucker	Shorthead redhorse	Darter - Etheostoma	
		Gravel chub	Rainbow darter	
Invertivore-Detritivore	**Planktivore**	Blacktail chubs	Johnny darter	
Common carp	Paddlefish	Sturgeon chub	Yellow perch	
	Skipjack herring	Shoal chub	Perches	
Invertivore-Omnivore	Bighead carp	Sicklefin chub	Darter - Percina	
Red shiner		Silver chub	Logperch	
Striped shiner		Shiners - Notropis	Madtoms	
		Emerald shiner	Stonecat madtom	
		River shiner	Freckled madtom	

Necessary Food Chain Species

The make-up of the fish community was classified into informally defined types (Table 5-6) including forage (typically small-bodied when fully grown), rough (large-bodied when fully grown, but generally not desired by anglers), game/commercial (targeted by anglers and/or commercial fishermen, often large-bodied when fully grown), pan (medium-bodied when fully grown and may be targeted or are desirable by-catch for anglers), and special (species of special management interest, in this case sturgeons and paddlefish).

Table 5-6 Classification of Missouri River fishes into forage, rough, game, pan and special categories for purpose of describing the fish community.

Forage	Rough	Game	Pan	Special
Herrings	Gizzard shad	Largemouth bass	Sunfish Family	Sturgeons
Minnows	Common carp	Spotted bass	White bass	Paddlefish
Killifish	Asian carps	Striped bass	Yellow perch	
Lampreys	Gars	Walleye		
Silversides	Suckers (Non-Buffalo)	Sauger		
Madtoms	Goldfish	Blue catfish		
Drums		Flathead catfish		
Mooneyes		Channel catfish		
Livebearers		Buffalos		
Darters				
Stonerollers				

The proportion of these fish types differed little across the four zones, either in terms of numbers or biomass (Figure 5-18), except that in the Discharge zone forage fish were more dominant in terms of numerical abundance than in other zones, and game fish (large catfishes) were more dominant in terms of biomass than in other zones. The data show that the necessary food chain species are present in all zones in similar proportions.

No Increase in Nuisance Species

The rough fish category consists of species that are typically tolerant of poor water quality and/or high temperatures and thus may outcompete less tolerant species under stressful conditions. Generally rough fish, and particularly nuisance species, are less desirable for human uses than are game, pan, or special category fishes. Asian carps, for example are a well-documented nuisance species that can be extremely abundant, alter the trophic structure of a water body, and even pose a danger to recreational boaters due to their escape response. One indication of potential harm from a thermal discharge might be an increased proportion of rough fish in the Thermally Exposed or Downstream zones. The numbers and proportions of rough fish in the Upstream Reference, Thermally Exposed, and Downstream zones are similar as shown in Figure 5-18. The most common species that would be considered a nuisance species, silver carp, showed very slight increases in areas exposed to the thermal discharge. They accounted for 1.7 percent of the catch in the Upstream Reference zone, 2.4 percent in the Thermally Exposed zone, and 1.9 percent in the Downstream zone (Table 5-3). Their contribution to total fish biomass ranged from 10 percent in the Upstream Reference zone to 12 percent in the Thermally Exposed and Downstream zones (Table 5-4). Another species often considered a nuisance species, common carp, had biomass of 14 percent upstream, but 13 percent and 12 percent in the Thermally Exposed and Downstream zones, respectively. Therefore, nuisance species have not become dominant as a result of the LEC thermal discharge.

Change in Commercial or Sport Species

Based on the classification of fish types in Table 5-6, commercial and/or sport species would be represented by the game and pan fish categories. The proportion of game and pan fish categories was similar among Upstream Reference, Thermally Exposed, and Downstream zones indicating the LEC discharge has not caused a change in the abundance of these species (Figure 5-18). Game and pan fish biomass were also similar between the three zones. The Discharge zone had a higher proportion of game fish (large catfish species) abundance and biomass than the other three zones, suggesting an attraction to the discharge either due directly to a preference for higher water temperatures, or due to the abundance of forage species. This demonstrates that LEC's thermal discharge did not cause a decrease in commercial or sport species.

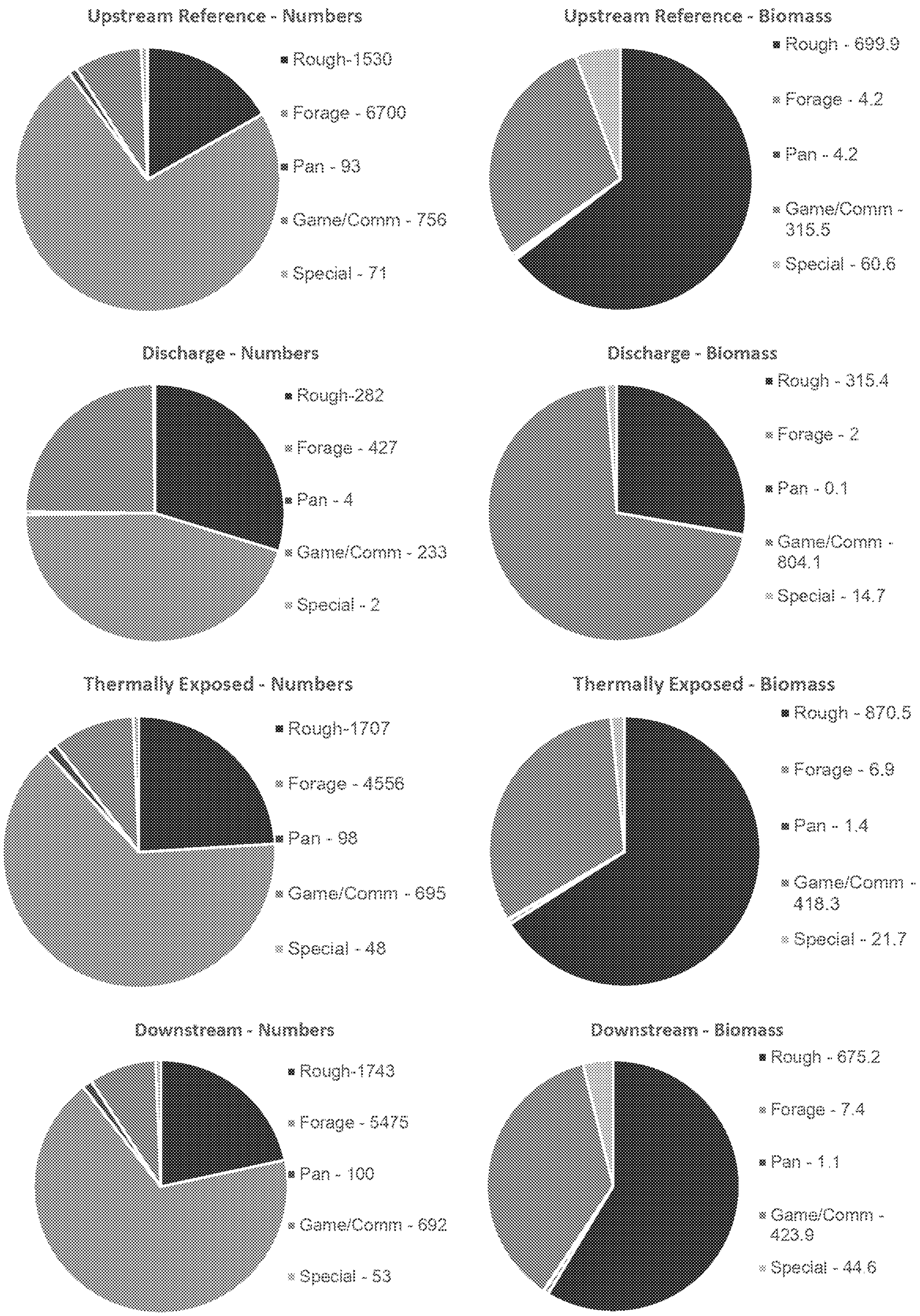


Figure 5-18 Composition of fisheries sampling results in rough, forage, pan, game, and special categories based on numerical abundance (left column) and total biomass in Kg (right) over all seasons and gear types.

Lack of Domination by Heat Tolerant Species

Some of the species in the community could be classified as heat-intolerant (environment in the LEC vicinity would be near their upper thermal tolerance limit) or heat-tolerant (environment in the LEC vicinity is well below their upper thermal tolerance limit). Species considered to be intolerant for the community are sauger, walleye, mooneye, goldeye, and white crappie (Appendix B Section B.2). Species considered to be thermally tolerant are bighead carp, silver carp, bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, emerald shiner, gizzard shad, longnose gar, shortnose gar, and river carpsucker (Appendix B Section B.2).

The abundances of heat intolerant species were similarly low in all zones. Heat tolerant species represented a higher proportion of the community than heat intolerant species in all zones. The proportion of heat tolerant species was slightly higher in the Discharge, Thermally Exposed, and Downstream zones relative to the Upstream Reference zone suggesting a possible effect of LEC thermal discharge on the number of heat tolerant species (Figure 5-19). This was not the case for biomass of heat tolerant species which was lowest in the Discharge zone.

Lack of Domination by Pollution Tolerant Species

Because chemical and organic pollution can be exacerbated by heat, it is also informative to see whether pollution intolerant species may have been replaced by pollution tolerant species in areas affected by a thermal discharge. The LEC community was classified as tolerant or intolerant to pollution based on Pearson et al. (2011), although many of the species are neither distinctly tolerant nor intolerant.

For the LEC discharge, there is no indication of a shift from pollution intolerant or to pollution tolerant species (Figure 5-20). In terms of numerical abundance, pollution intolerant species comprised approximately 2 percent of the community in all zones, and pollution tolerant species were relatively less abundant in the Thermally Exposed (22 percent) and Downstream (26 percent) zones than in the Upstream Reference zone (36 percent). Trends across zones were similar for biomass, with intolerant species ranging from 6 percent to 8 percent, except for the Discharge zone, and pollution tolerant species from 24 percent to 25 percent.

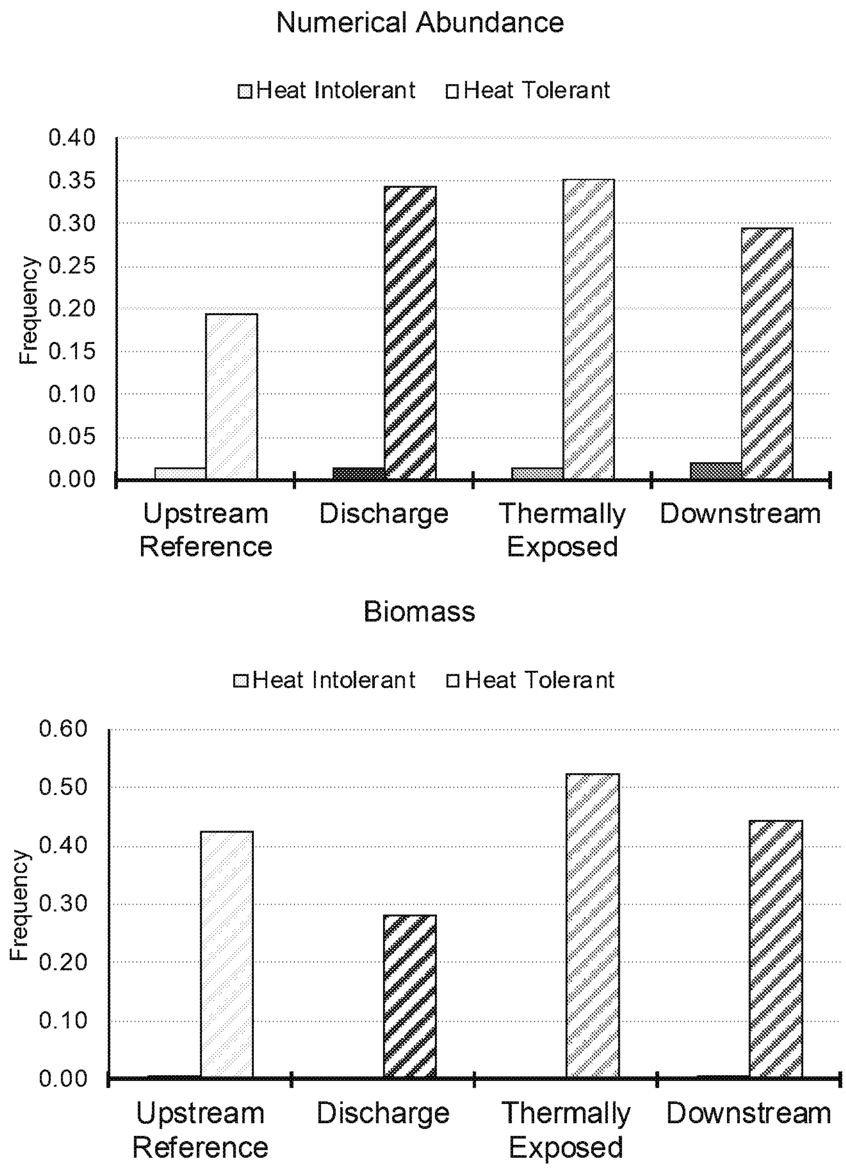


Figure 5-19 Fractions of number of fish (top) and biomass (bottom) comprised of heat-intolerant species (solid) and heat-tolerant species (hatched) in fisheries sampling at the LEC in 2017-2018 for all gear and seasons combined.

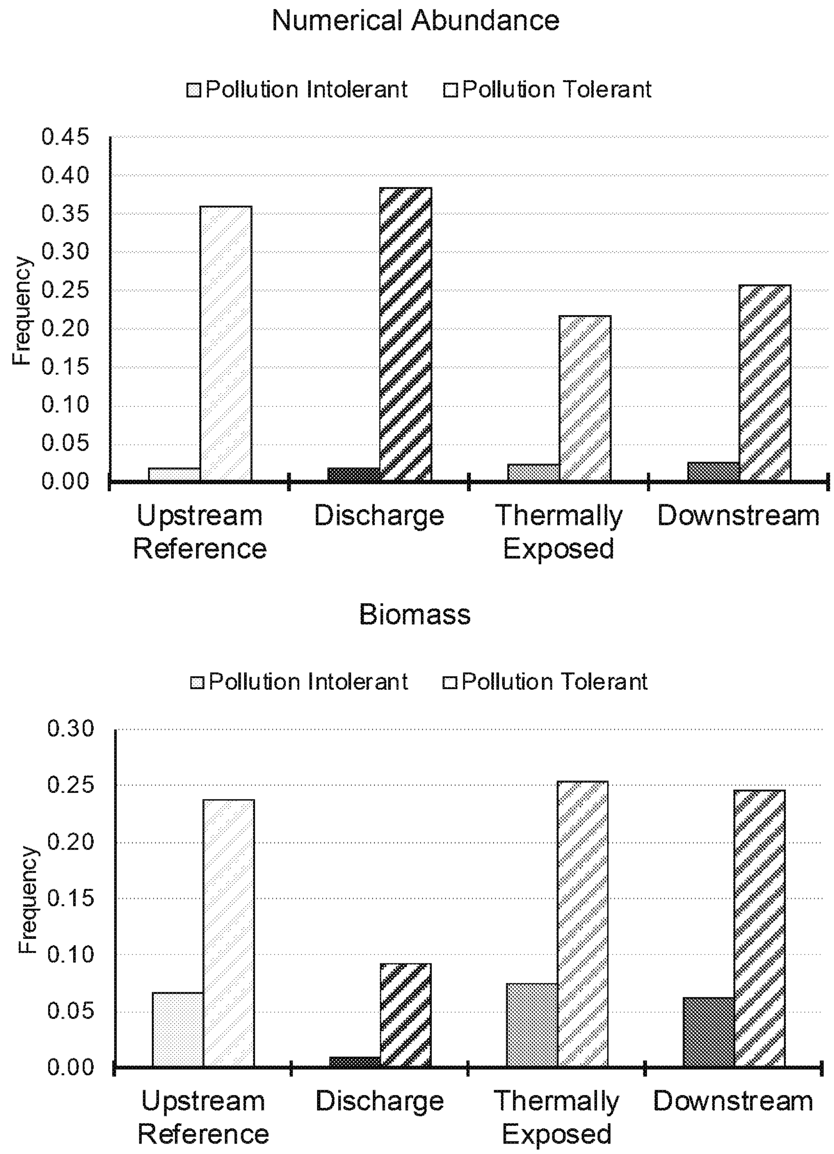


Figure 5-20 Fractions of number of fish (top) and biomass (bottom) comprised of pollution-intolerant species (solid) and pollution-tolerant species (hatched) in fisheries sampling at the LEC in 2017-2018 for all gear and seasons combined.

5.4.1.4 Overall Weight of Evidence

While the evaluation above does not document any clear effect of the LEC's thermal discharge on the individual community metrics, it is also helpful to evaluate patterns across all metrics to see if there are any consistent patterns suggestive of thermal effects. For example, is the Upstream Reference Zone consistently better across all metrics than the thermally exposed zones? This evaluation was done using a quantitative Weight-of-Evidence approach. In this analysis, a "standardized difference", essentially a t-statistic, was calculated for each ecological metric for each combination of sampling gear and season. Each standardized difference was formulated so that it would have a negative value if consistent with harm, and a positive value if inconsistent. Standardized differences were calculated for both numbers of fish and for biomass so that both aspects of the community could be analyzed.

$$Standardized\ Difference = X \frac{V_{TE\ or\ D} - V_{Upstream}}{\sqrt{se(V_{TE\ or\ D})^2 + se(V_{Upstream})^2}}$$

where

X = multiplier set to -1 or +1 so that the difference is negative if the change direction is consistent with harm

V = value of the metric

se(V) = standard error of the metric

Only metrics which had a directional (better vs worse) component were used. Metrics used were:

Metric	Basis	Directional
Abundance	Numbers	High better than low
Abundance	Biomass	High better than low
Diversity ^0D (Species Richness)	Numbers	High better than low
Diversity ^1D (transform of H')	Numbers	High better than low
Diversity ^2D (Inverse Gini-Simpson)	Numbers	High better than low
Diversity ^3D (very abundant species)	Numbers	High better than low
Fraction Non-Rough	Numbers	High better than low
Fraction Non-Rough	Biomass	High better than low
Fraction Heat Intolerant	Numbers	High better than low
Fraction Heat Intolerant	Biomass	High better than low
Fraction Heat Tolerant	Numbers	Low better than high
Fraction Heat Tolerant	Biomass	Low better than high
Fraction Pollution Intolerant	Numbers	High better than low
Fraction Pollution Intolerant	Biomass	High better than low
Fraction Pollution Tolerant	Numbers	Low better than high
Fraction Pollution Tolerant	Biomass	Low better than high

In a case where there is no spatial change between zones, these standardized differences would be expected to have a distribution centered at 0, with approximately equal proportions positive and negative (Figure 5-21). If there were prior appreciable harm due to the thermal discharge, the distribution of differences would be shifted toward negative values.

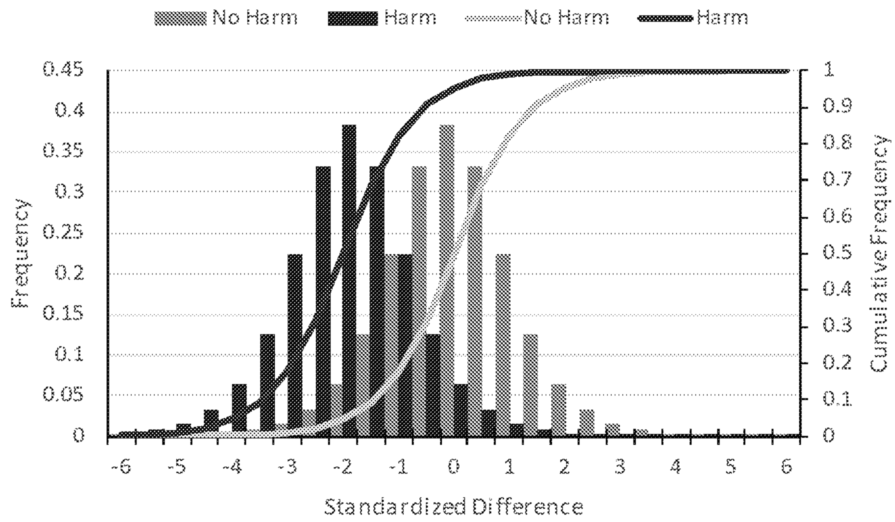


Figure 5-21 Idealized pattern of standardized differences if there were no harm (green) and if there were appreciable harm.

The overall pattern of standardized differences across all the metrics examined in the spatial analysis is not consistent with harm from the thermal discharge (Figure 5-22). Distributions of differences for both the Upstream Reference zone compared to the Thermally Exposed zone and the Upstream Reference zone compared to the Downstream zone were centered near zero and spread nearly equally to positive and negative values. The mean for the Thermally Exposed zone was -0.611, suggesting potentially a slight degradation in the Thermally Exposed zone relative to the Upstream Reference zone, while the mean for the Downstream zone was -0.053, suggestive of conditions similar to those in the Upstream Reference zone. However, the shift in both distributions from the expected value of 0 (for no effect) is within two standard errors, which indicates that observed shifts are not likely biologically meaningful, particularly for the Downstream zone.

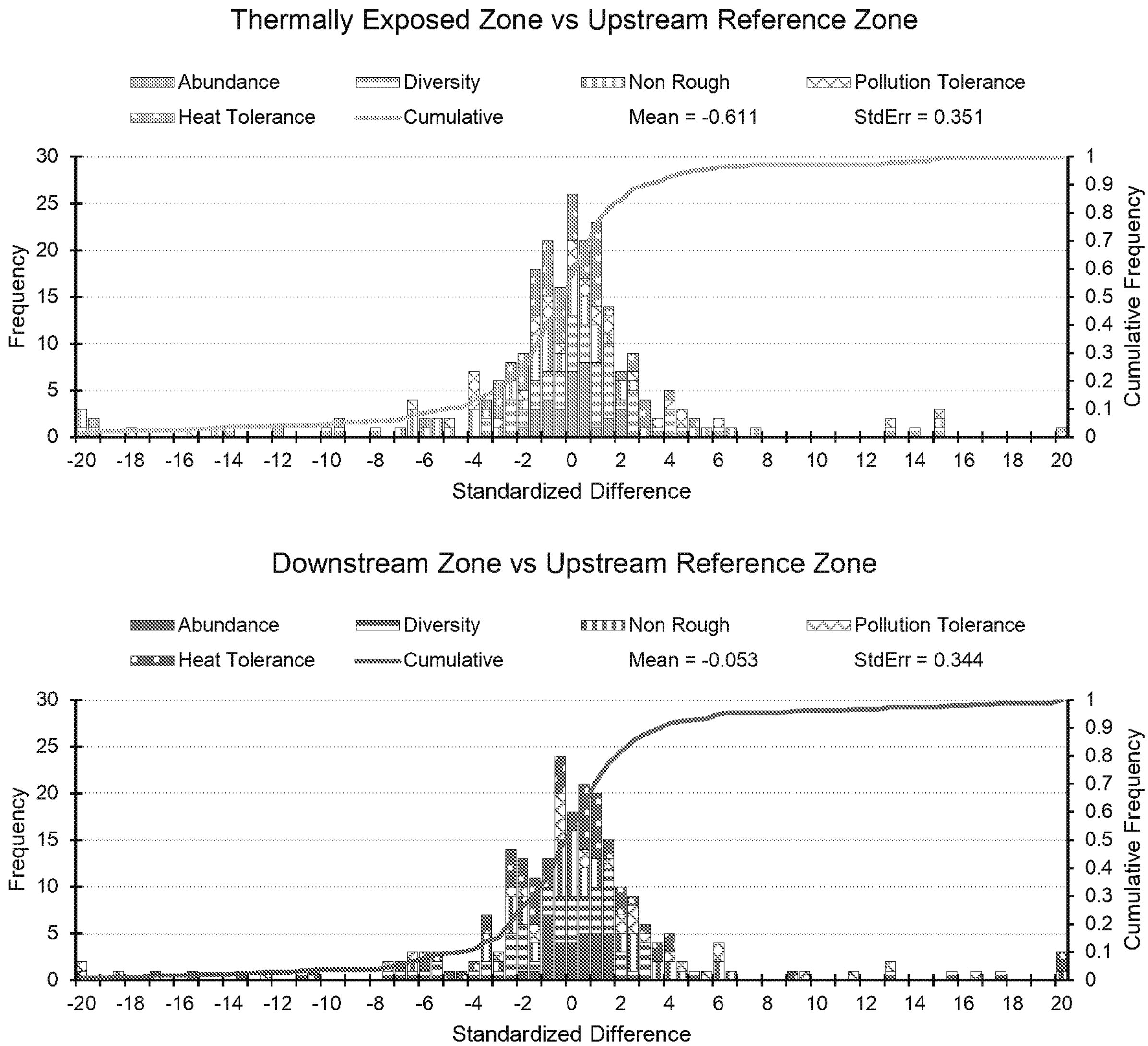


Figure 5-22 Distribution of standardized differences between ecological metrics for the Thermally Exposed Zone and Upstream Refence zone (top) and Downstream zone and Upstream Reference Zone (bottom) over all gear, seasons, and metrics.

5.4.2 Benthic Macroinvertebrate Community

The benthic macroinvertebrate sampling program implemented by Wood in the vicinity of the LEC collected almost 94,000 organisms during 2017-2018 (Table 5-7). The H-D samplers, which tend to collect drifting organisms, collected over 72,000 organisms while the Ponar dredge, which collects benthic infaunal organisms, contained over 21,000 organisms. Abundance in H-D collections were generally similar among the four sampling zones, ranging from approximately 16,000 to 20,000, while abundance in Ponar collections were approximately 600 in the Discharge Zone, but ranged from 5,000 to 9,000 in the other three zones.

The minimum number of families[3] of benthic macroinvertebrates collected in H-D samples was 20 in the Discharge zone, and 29-31 in the other zones. The zonal variation in number of distinct species was similar, with 53 species in the Discharge zone, and 86-88 in the other zones. The number of families in Ponar samples ranged from 10 in the Discharge zone to 25-29in the other zones, while distinct species ranged from 37 in the Discharge zone to 65-79 in the other zones.

Table 5-7 Total organisms collected, and minimum number of families and species for each sampling zone and gear in macroinvertebrate sampling in LEC vicinity in 2017-2018.

Zone	Hester-Dendy			Ponar		
	Count	Minimum Families	Minimum Species	Count	Minimum Families	Minimum Species
Upstream	20,587	29	86	8,765	25	65
Discharge	15,735	20	53	564	10	37
Thermal	20,413	31	92	5,261	29	70
Downstream	15,498	30	88	7,056	27	79
Total	72,233			21,646		

The number of organisms for individual families is provided in Table 5-8 and Table 5-9. Summary table for all benthic macroinvertebrate data are presented in Appendix B Section B.1.

5.4.2.1 Overall Abundance

Sample densities (number per 0.1 m^2) of total macroinvertebrates were calculated for each sampling gear in each season and zone. For both gears, substantial variation occurred among season and zone. For H-D samples, densities in the Discharge zone were distinctly higher than in other zones in all seasons (Figure 5-23). Densities in the Thermally Exposed zone were the same or greater than those in the Upstream Reference zone in all seasons. Downstream zone densities were similar to those in the Upstream Reference zone in all seasons but summer when they were lower. For Ponar samples, the Discharge zone consistently had the lowest densities, and the Upstream Reference Zone the highest, except in winter. Downstream zone densities were higher than in the Thermally Exposed zone. These results demonstrate that the LEC's thermal discharge did not reduce the number of drifting organisms. On the other hand, the reduced abundance of infaunal organisms in the discharge canal could be related to heat, water turbulence or/or sediment instability. Regardless of the cause, there were no effects observed outside the discharge canal.

[3] In determining the minimum number of families collected, organisms identified at higher taxonomic levels, e.g. orders, class, phylum, were considered to be 1 additional family if no organisms within that classification were identified to the level of family. Minimum number of species were determined similarly for organisms identified to genus or higher levels. For example, a genus with no organisms identified to species was considered as 1 additional species.

Table 5-8 Counts of organism by family and minimum number of species in Hester-Dendy sampling in vicinity of the LEC in 2017-2018.

Class	Order	Family	Upstream Reference			Discharge			Thermally Exposed			Downstream		
			Count	Min. Species	Fraction	Count	Min. Species	Fraction	Count	Min. Species	Fraction	Count	Min. Species	Fraction
Arachnida	Trombidiformes	Hydrachnidia	7	1	0.0003	5	1	0.0003	2	1	0.0001	4	1	0.0003
Bivalvia	Veneroida	Corbiculidae	1	1	0.0000	0	0	0	2	1	0.0001	1	1	0.0001
Bivalvia	Veneroida	Dreissenidae	10	1	0.0005	0	0	0	20	1	0.001	6	1	0.0004
Clitellata			0	0	0.0000	1	0	0.0001	3	0	0.0001	2	0	0.0001
Clitellata	Hirudinida	Glossiphoniidae	0	0	0.0000	0	0	0	2	1	0.0001	0	0	0
Clitellata	Tubificida	Naididae	79	7	0.0038	67	4	0.0043	86	9	0.0042	75	7	0.0048
Gastropoda	Basommatophora	Ancylidae	6	1	0.0003	2	1	0.0001	1	1	0	4	1	0.0003
Gastropoda	Basommatophora	Physidae	0	0	0.0000	1	1	0.0001	4	1	0.0002	3	1	0.0002
Hydrozoa	Anthoathecatae	Hydridae	2	1	0.0001	0	0	0	12	1	0.0006	10	1	0.0006
Insecta			172	0	0.0084	42	0	0.0027	250	0	0.0122	403	0	0.026
Insecta	Coleoptera	Elmidae	0	0	0.0000	0	0	0	0	0	0	3	2	0.0002
Insecta	Diptera	Ceratopogonidae	1	1	0.0000	2	2	0.0001	0	0	0	0	0	0
Insecta	Diptera	Chaoboridae	0	0	0.0000	0	0	0	0	0	0	4	1	0.0003
Insecta	Diptera	Chironomidae	8364	34	0.4063	2503	18	0.1591	7559	36	0.3703	5290	35	0.3413
Insecta	Diptera	Empididae	0	0	0.0000	0	0	0	0	0	0	1	1	0.0001
Insecta	Diptera	Simuliidae	0	0	0.0000	3	1	0.0002	1	1	0	0	0	0
Insecta	Diptera	Tabanidae	0	0	0.0000	0	0	0	0	0	0	4	1	0.0003
Insecta	Ephemeroptera		35	0	0.0017	61	0	0.0039	4	0	0.0002	22	0	0.0014
Insecta	Ephemeroptera	Baetidae	1749	1	0.0850	1217	1	0.0773	1030	1	0.0505	1286	1	0.083
Insecta	Ephemeroptera	Caenidae	768	2	0.0373	594	2	0.0378	398	2	0.0195	1144	2	0.0738
Insecta	Ephemeroptera	Ephemeridae	17	1	0.0008	0	0	0	8	1	0.0004	0	0	0
Insecta	Ephemeroptera	Heptageniidae	1759	6	0.0854	493	3	0.0313	1607	5	0.0787	1401	7	0.0904
Insecta	Ephemeroptera	Isonychiidae	399	3	0.0194	98	3	0.0062	288	3	0.0141	114	3	0.0074
Insecta	Ephemeroptera	Leptohyphidae	61	1	0.0030	10	1	0.0006	33	1	0.0016	36	1	0.0023
Insecta	Ephemeroptera	Palingeniidae	1	1	0.0000	0	0	0	1	1	0	0	0	0
Insecta	Ephemeroptera	Polymitarcyidae	3	1	0.0001	0	0	0	1	1	0	0	0	0

Class	Order	Family	Upstream Reference			Discharge			Thermally Exposed			Downstream		
			Count	Min. Species	Fraction	Count	Min. Species	Fraction	Count	Min. Species	Fraction	Count	Min. Species	Fraction
Insecta	Ephemeroptera	Potamanthidae	2	1	0.0001	0	0	0	1	1	0	2	1	0.0001
Insecta	Megaloptera	Corydalidae	37	2	0.0018	10	1	0.0006	16	2	0.0008	13	1	0.0008
Insecta	Odonata		0	0	0.0000	0	0	0	1	0	0	2	0	0.0001
Insecta	Odonata	Coenagrionidae	29	1	0.0014	0	0	0	78	2	0.0038	47	1	0.003
Insecta	Odonata	Corduliidae	38	2	0.0018	0	0	0	18	2	0.0009	27	2	0.0017
Insecta	Odonata	Gomphidae	3	1	0.0001	0	0	0	3	1	0.0001	5	1	0.0003
Insecta	Plecoptera		3	0	0.0001	3	0	0.0002	25	0	0.0012	0	0	0
Insecta	Plecoptera	Perlidae	168	5	0.0082	68	4	0.0043	132	5	0.0065	121	4	0.0078
Insecta	Plecoptera	Perlodidae	31	2	0.0015	32	2	0.002	69	2	0.0034	28	2	0.0018
Insecta	Plecoptera	Taeniopterygidae	2	1	0.0001	2	2	0.0001	2	1	0.0001	4	1	0.0003
Insecta	Trichoptera		15	0	0.0007	10	0	0.0006	3	0	0.0001	6	0	0.0004
Insecta	Trichoptera	Hydropsychidae	6598	3	0.3205	10489	3	0.6666	8560	3	0.4193	5261	3	0.3395
Insecta	Trichoptera	Hydroptilidae	16	1	0.0008	2	1	0.0001	6	1	0.0003	15	1	0.001
Insecta	Trichoptera	Leptoceridae	6	1	0.0003	0	0	0	6	1	0.0003	1	1	0.0001
Insecta	Trichoptera	Polycentropodidae	193	2	0.0094	5	1	0.0003	166	2	0.0081	94	2	0.0061
Trepaxonemata			0	0	0.0000	0	0	0	0	0	0	1	0	0.0001
Trepaxonemata	Neoophora	Planariidae	12	1	0.0006	15	1	0.001	15	1	0.0007	58	1	0.0037
Totals			20587	86		15735	53		20413	92		15498	88	

Table 5-9 Counts of organism by family and minimum number of species in Ponar sampling in vicinity of the LEC in 2017-2018.

Class	Order	Family	Upstream Reference			Discharge			Thermally Exposed			Downstream		
			Count	Minimum Species	Fraction	Count	Minimum Species	Fraction	Count	Minimum Species	Fraction	Count	Minimum Species	Fraction
Arachnida	Trombidiformes	Hydrachnidia	0	0	0.0000	1	1	0.0018	0	0	0	0	0	0
Bivalvia			0	0	0.0000	0	0	0	0	0	0	1	0	0.0001
Bivalvia	Unionoida	Unionidae	0	0	0.0000	0	0	0	0	0	0	1	1	0.0001
Bivalvia	Veneroida	Corbiculidae	16	1	0.0018	8	1	0.0142	7	1	0.0013	6	1	0.0009
Bivalvia	Veneroida	Dreissenidae	7	1	0.0008	0	0	0	1	1	0.0002	14	1	0.002
Clitellata			987	0	0.1126	38	0	0.0674	1169	0	0.2222	1438	0	0.2038
Clitellata	Hirudinida	Glossiphoniidae	1	1	0.0001	0	0	0	1	1	0.0002	2	2	0.0003
Clitellata	Lumbriculida	Lumbriculidae	4	1	0.0005	0	0	0	3	1	0.0006	10	1	0.0014
Clitellata	Tubificida	Naididae	5454	4	0.6222	260	7	0.461	2929	8	0.5567	3968	11	0.5624
Entognatha	Collembola	Isotomidae	45	1	0.0051	0	0	0	3	1	0.0006	7	1	0.001
Gastropoda	Basommatophora	Ancylidae	2	1	0.0002	0	0	0	0	0	0	0	0	0
Gastropoda	Basommatophora	Planorbidae	0	0	0.0000	0	0	0	1	1	0.0002	1	1	0.0001
Insecta			0	0	0.0000	0	0	0	1	0	0.0002	0	0	0
Insecta	Coleoptera		3	0	0.0003	0	0	0	1	0	0.0002	0	0	0
Insecta	Coleoptera	Elmidae	3	1	0.0003	0	0	0	0	0	0	3	2	0.0004
Insecta	Coleoptera	Staphylinidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Diptera		1	0	0.0001	1	0	0.0018	31	0	0.0059	0	0	0
Insecta	Diptera	Ceratopogonidae	7	2	0.0008	3	2	0.0053	4	2	0.0008	8	4	0.0011
Insecta	Diptera	Chaoboridae	2	1	0.0002	0	0	0	11	1	0.0021	7	1	0.001
Insecta	Diptera	Chironomidae	942	34	0.1075	77	20	0.1365	477	29	0.0907	833	33	0.1181
Insecta	Diptera	Dolichopodidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Diptera	Psychodidae	2	1	0.0002	0	0	0	2	1	0.0004	4	1	0.0006
Insecta	Diptera	Simuliidae	1	1	0.0001	0	0	0	0	0	0	0	0	0
Insecta	Ephemeroptera		5	0	0.0006	0	0	0	16	0	0.003	4	0	0.0006
Insecta	Ephemeroptera	Baetidae	1	1	0.0001	1	1	0.0018	0	0	0	3	1	0.0004
Insecta	Ephemeroptera	Caenidae	2	1	0.0002	0	0	0	1	1	0.0002	6	1	0.0009

Class	Order	Family	Upstream Reference			Discharge			Thermally Exposed			Downstream		
			Count	Minimum Species	Fraction	Count	Minimum Species	Fraction	Count	Minimum Species	Fraction	Count	Minimum Species	Fraction
Insecta	Ephemeroptera	Ephemeridae	1017	3	0.1160	3	1	0.0053	409	3	0.0777	430	3	0.0609
Insecta	Ephemeroptera	Heptageniidae	2	1	0.0002	0	0	0	1	1	0.0002	4	1	0.0006
Insecta	Ephemeroptera	Isonychiidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Ephemeroptera	Leptohyphidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Ephemeroptera	Palingeniidae	115	1	0.0131	97	1	0.172	85	1	0.0162	189	1	0.0268
Insecta	Ephemeroptera	Polymitarcyidae	19	1	0.0022	0	0	0	8	2	0.0015	6	2	0.0009
Insecta	Hemiptera		0	0	0.0000	0	0	0	0	0	0	2	1	0.0003
Insecta	Hemiptera	Aphididae	0	0	0.0000	0	0	0	2	1	0.0004	0	0	0
Insecta	Hemiptera	Corixidae	2	1	0.0002	0	0	0	1	1	0.0002	0	0	0
Insecta	Lepidoptera		0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Megaloptera	Corydalidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Odonata	Corduliidae	0	0	0.0000	0	0	0	1	1	0.0002	3	1	0.0004
Insecta	Odonata	Gomphidae	5	1	0.0006	3	1	0.0053	9	2	0.0017	20	2	0.0028
Insecta	Plecoptera		1	0	0.0001	0	0	0	1	0	0.0002	0	0	0
Insecta	Plecoptera	Perlidae	1	1	0.0001	0	0	0	0	0	0	0	0	0
Insecta	Plecoptera	Perlodidae	0	0	0.0000	0	0	0	1	1	0.0002	4	1	0.0006
Insecta	Plecoptera	Taeniopterygidae	0	0	0.0000	0	0	0	0	0	0	1	1	0.0001
Insecta	Trichoptera		0	0	0.0000	0	0	0	0	0	0	2	0	0.0003
Insecta	Trichoptera	Hydropsychidae	116	2	0.0132	72	2	0.1277	77	2	0.0146	76	2	0.0108
Insecta	Trichoptera	Hydroptilidae	0	0	0.0000	0	0	0	0	0	0	1	1	0.0001
Insecta	Trichoptera	Leptoceridae	1	1	0.0001	0	0	0	0	0	0	0	0	0
Insecta	Trichoptera	Polycentropodidae	1	1	0.0001	0	0	0	2	1	0.0004	2	1	0.0003
Totals			8765	65		564	37		5261	70		7056	79	

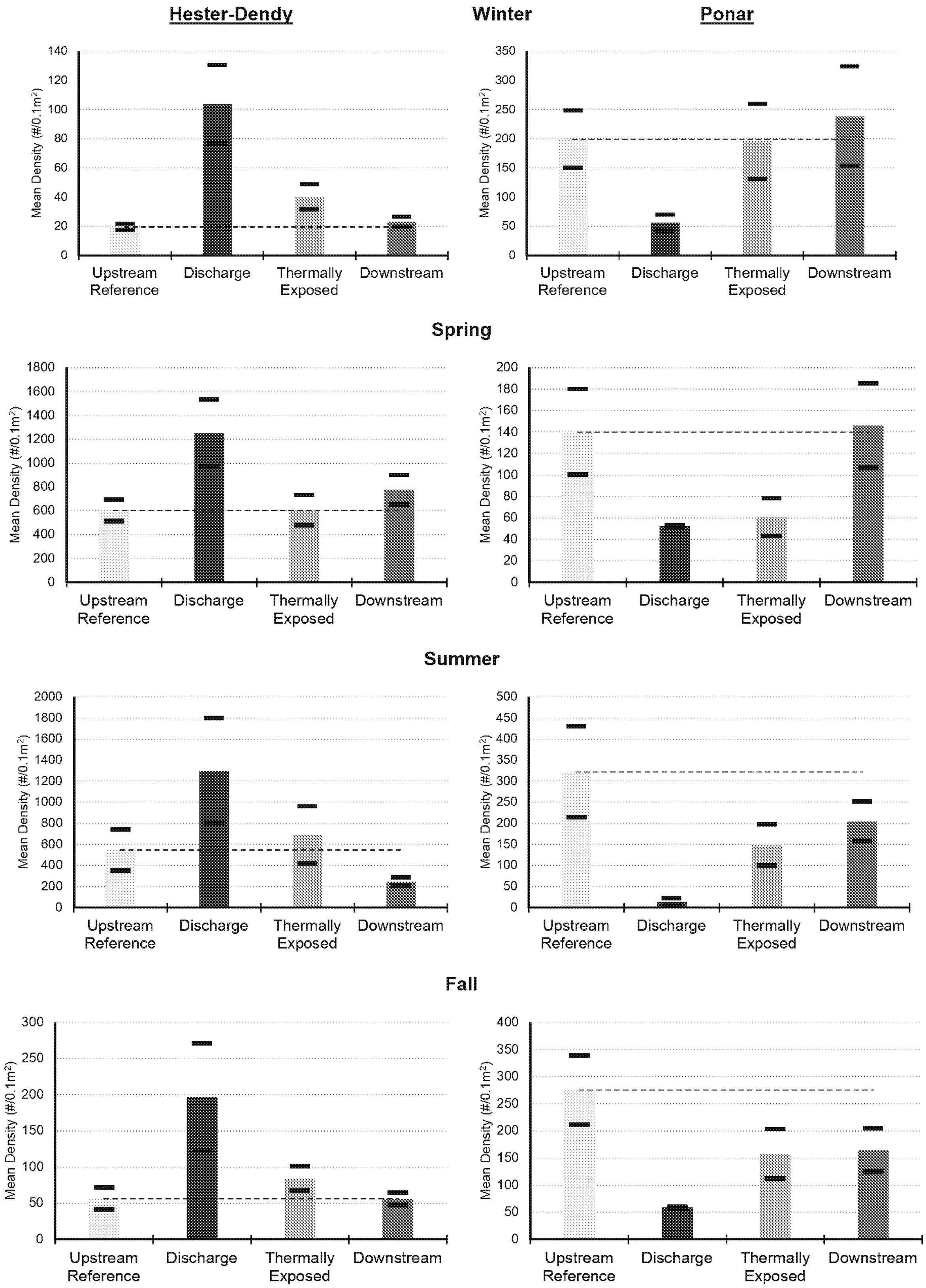


Figure 5-23 Mean density (#/0.1m^2) of macrobenthos in sampling at the LEC in 2017-2018 for each season, gear type, and zone. Back bars indicate +/- 1 standard error from mean.

5.4.2.2 Capability to Sustain Itself

Seasonal density patterns (relative to maximum seasonal density) for the drift component of the macroinvertebrate community sampled with H-D gear were very similar among the four sampling zones (Figure 5-24). The only departure from the pattern of high densities in spring and summer and low densities in winter and fall was that summer densities in the Downstream zone were lower relative to maximum density than in the other zones (Figure 5-24 top). Reasons for this pattern are unknown but are clearly not related to the LEC's thermal discharge.

For the Ponar samples of the benthic infauna, the Upstream Reference zone had winter, summer, and fall densities greater than 90 percent of the maximum, with spring relative density only 55 percent of the maximum (Figure 5-24 bottom). For the Thermally Exposed and Downstream zones, densities were highest in winter and lowest in summer, and well below maximum (43 percent to 64 percent) in summer and fall. The Discharge zone had maximum densities in spring and minimum densities in summer.

Some disturbance, such as earlier maturation and thus drifting, to benthic infauna is suggested by the lower spring, summer, and fall densities in the Thermally Exposed and Downstream zones relative to the Upstream Reference zone. However, both the epifaunal and infaunal macroinvertebrate communities demonstrate the ability to sustain themselves in the Thermally Exposed and Downstream zones.

5.4.2.3 Community Characteristics

Diversity

Due to the differences in taxonomic level (class, order, family, etc.) of identification of the benthic macroinvertebrates, diversity was calculated at the family level because most organisms could be identified to this level. Other than fewer families being observed in Discharge zone samples than in other zones (at q = 0), there was no consistent pattern of differences in diversity among the other zones (Figure 5-25). Diversity was similar between the Upstream Reference, Thermally Exposed, and Downstream zones in all seasons at all levels of q in both the H-D and Ponar samples. Overall, more families were collected in the H-D samples than in the Ponar samples (q = 0), and diversity at higher values of q was also higher in H-D samples, indicating that the drift community is less dominated by a few families than is the in-faunal community. This analysis demonstrates that the LEC thermal discharge has not adversely affected the benthic macroinvertebrate diversity in the Thermally Exposed and Downstream zones.

Dominance

All zones, except for the Discharge zone, had similar proportions comprised of the dominant benthic macroinvertebrate groups (Figure 5-26). For the Upstream Reference, Thermally Exposed, and Downstream zones, H-D samples were dominated by Diptera (flies – 34 percent to 41 percent), Ephemeroptera (mayflies – 17 percent to 26 percent), and Trichoptera (caddisflies – 33 percent to 43 percent) with Plecoptera (stoneflies) and other combined taxa ranging from 3 percent to 5 percent. In the Discharge zone, Tricoptera dominated (67 percent), followed by Diptera (16 percent) and Ephemeroptera (16 percent).

For Ponar samples of the benthic infauna, the composition was also similar among zones, but with the Discharge zone being the most different from the others. For the Upstream Reference, Thermally Exposed, and Downstream zones, Tubificida was the dominant group ranging from 56 percent to 62 percent, followed by Diptera at 10 percent to 12 percent, and Ephemeroptera 9 percent to 13 percent. All other groups were comprised 14 percent to 24 percent, but most of these were undifferentiated Class Clitellata (11 percent to 22 percent). The Discharge zone was only different from the other zones in that Tubificida accounted for only 46 percent of the sampled organisms, and that Trichoptera were 13% rather than 1-2 percent. While there is some evidence of effects on the macrobenthic component within the Discharge Canal, the LEC thermal discharge has not adversely affected the benthic macroinvertebrate community in the Thermally Exposed and Downstream zones in the main river.

Dominance by Pollution Tolerant Species

Because the Ephemeroptera, Plecoptera, and Trichoptera orders generally require good water and sediment quality and other habitat conditions, the number of species in these orders and fraction of the community comprised of these groups are often used as indicators of habitat quality. In H-D samples the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) species in the Thermally Exposed and Downstream zones was generally similar (slightly higher or lower) to the Upstream Reference zone while the fraction of EPT species was typically slightly higher in the Upstream Reference zone (Figure 5-27). Ponar samples showed a similar pattern, however the fraction of EPT species was typically lower due to the higher abundance of Tubificida in the sediment. These patterns indicate that the LEC thermal discharge has not caused the areas downstream to be dominated by pollution tolerant species.

Dominance by Heat Tolerant Species

Some EPT taxa are more intolerant of high temperatures than others. A literature search identified the following EPT taxa as having an upper incipient lethal temperature of 86°F (30°C) or less: Baetidae, *Caenis* sp., *Hexagenia limbata*, *Heptagenia* sp., Heptageniiidae, *Stenonema femoratum*, *Acroneuria* sp., Perlidae, Taeniopterygidae, *Taeniopteryx* sp., *Hydroptila* sp., and Hydroptillidae, (Appendix B Table B-29). Overall, these heat-intolerant taxa were approximately 8% of the total EPTorganisms sampled by the Hester-Dendy and 30% of EPT organisms for Ponar samples.

In H-D samples, the proportion of heat-intolerant EPT organisms was lower in the Thermally Exposed zone than in the Upstream Reference zone, except in the fall (Figure 5-28). Downstream zone values were nearly the same as the Upstream Reference zone in spring and summer, but distinctly greater than Upstream Reference zone values in winter, but lower in the fall. Samples from the Discharge zone exhibited a lower proportion of heat-intolerant relative to other zones in all seasons.

For Ponar samples, heat-intolerant taxa were more prevalent in winter and fall seasons. The Thermally Exposed zone had a lower fraction of heat-intolerant than the Upstream Reference zone in the spring, but similar fractions in all other seasons, while the Downstream zone had a higher fraction in the winter, lower fraction in the fall, and similar fractions in spring and summer.

The heat intolerant EPT taxa comprise a fraction of the EPT organisms and an even smaller fraction of the overall benthic macroinvertebrates sampled. All zones appear to be similarly dominated by heat tolerant taxa, with the exception the benthic infauna sampled by Ponar in the fall, and there is no indication that the proportion of heat intolerant taxa are being reduced in favor of heat tolerant taxa in the Thermally Exposed and Downstream zones.

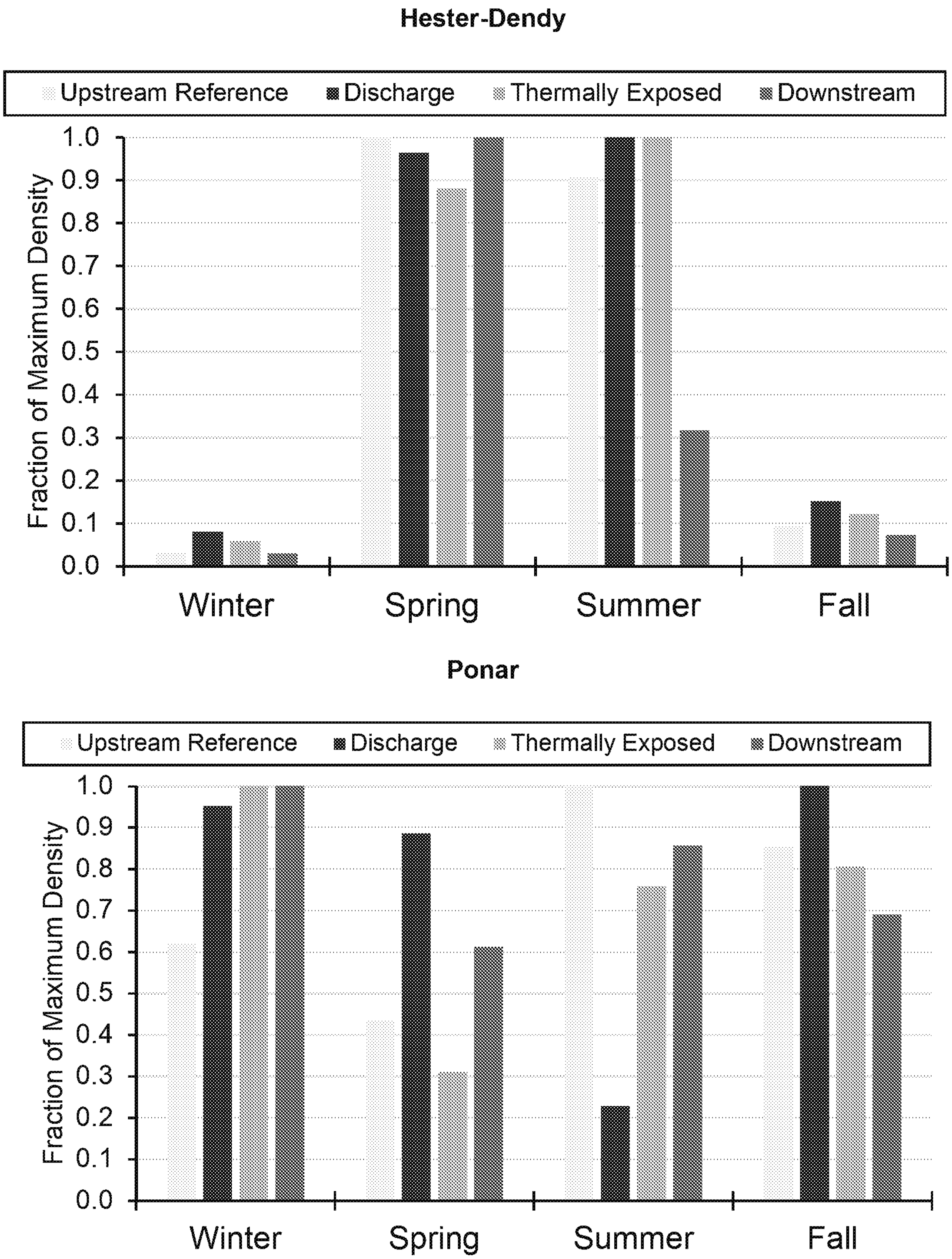


Figure 5-24 Seasonal pattern of variation in relative density of macroinvertebrates of Upstream, Discharge, Thermal, and Downstream zones, in Hester-Dendy samples (top) and Ponar samples (bottom) in the LEC vicinity in 2017-2018.

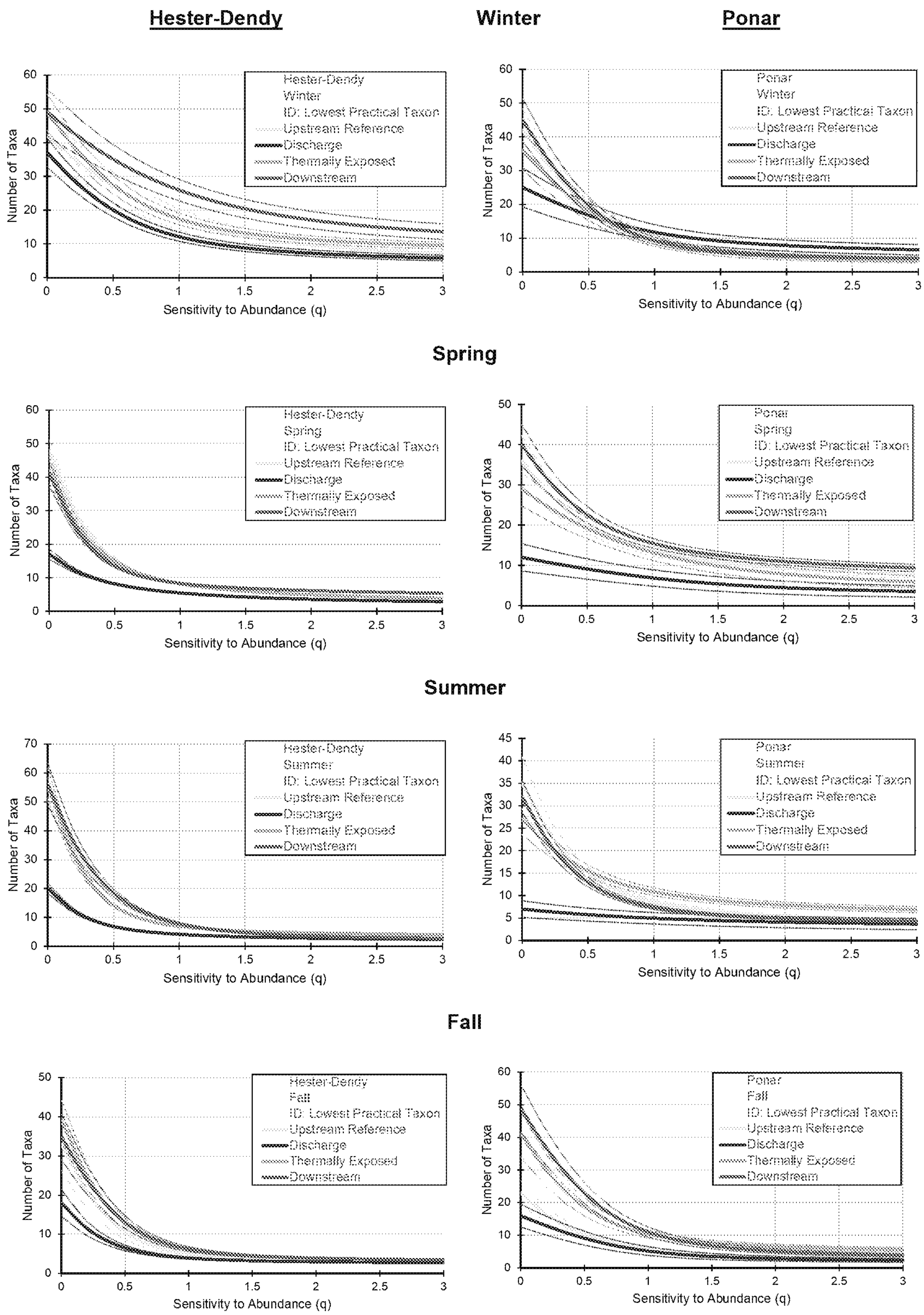


Figure 5-25 Diversity profiles of macrobenthos sampled at the LEC in 2017-2018 for each gear type and season. Dashed lines for numerical profiles indicate +/- 2 standard deviations around estimate.

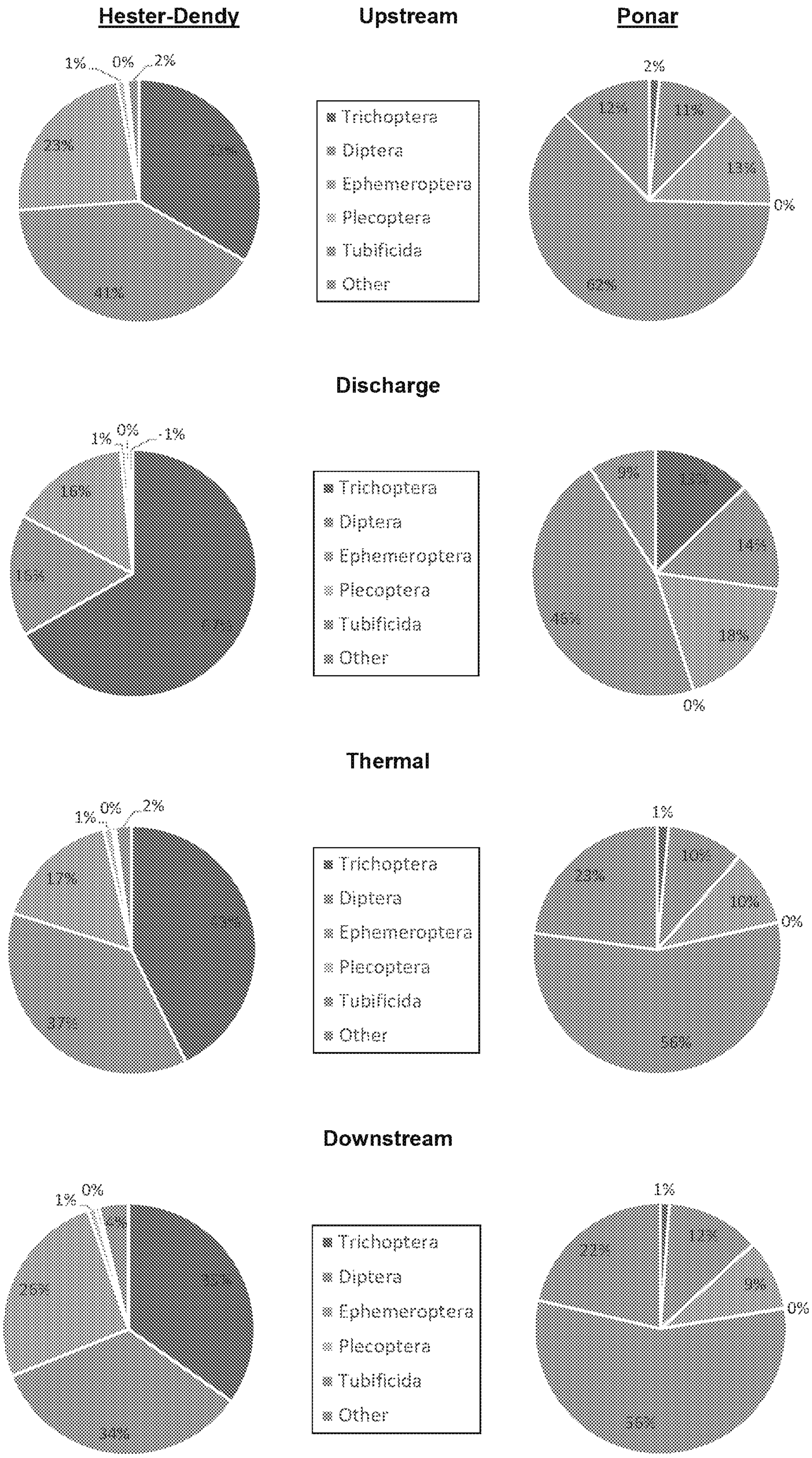


Figure 5-26 Major groups of benthic macroinvertebrates in sampling near the LEC in 2017-2018.

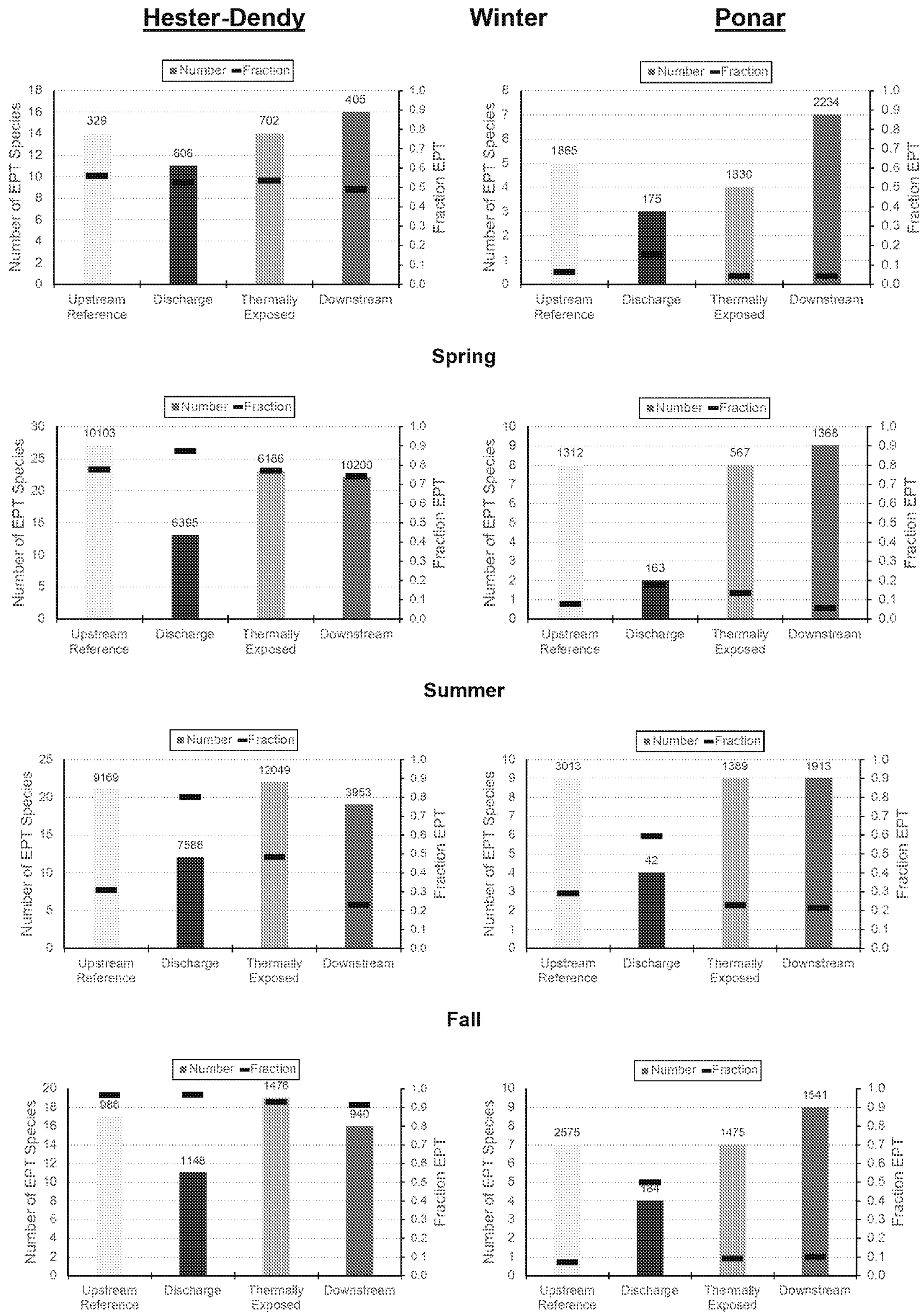


Figure 5-27 Contribution of Ephemeroptera, Plecoptera, and Trichoptera species to the total sample for Hester-Dendy and Ponar samples at the LEC in 2017-2018. Colored columns represent the number of EPT species. Numbers above the column is total number of organisms. Black horizontal bars are the fraction of the community comprised of EPT species.

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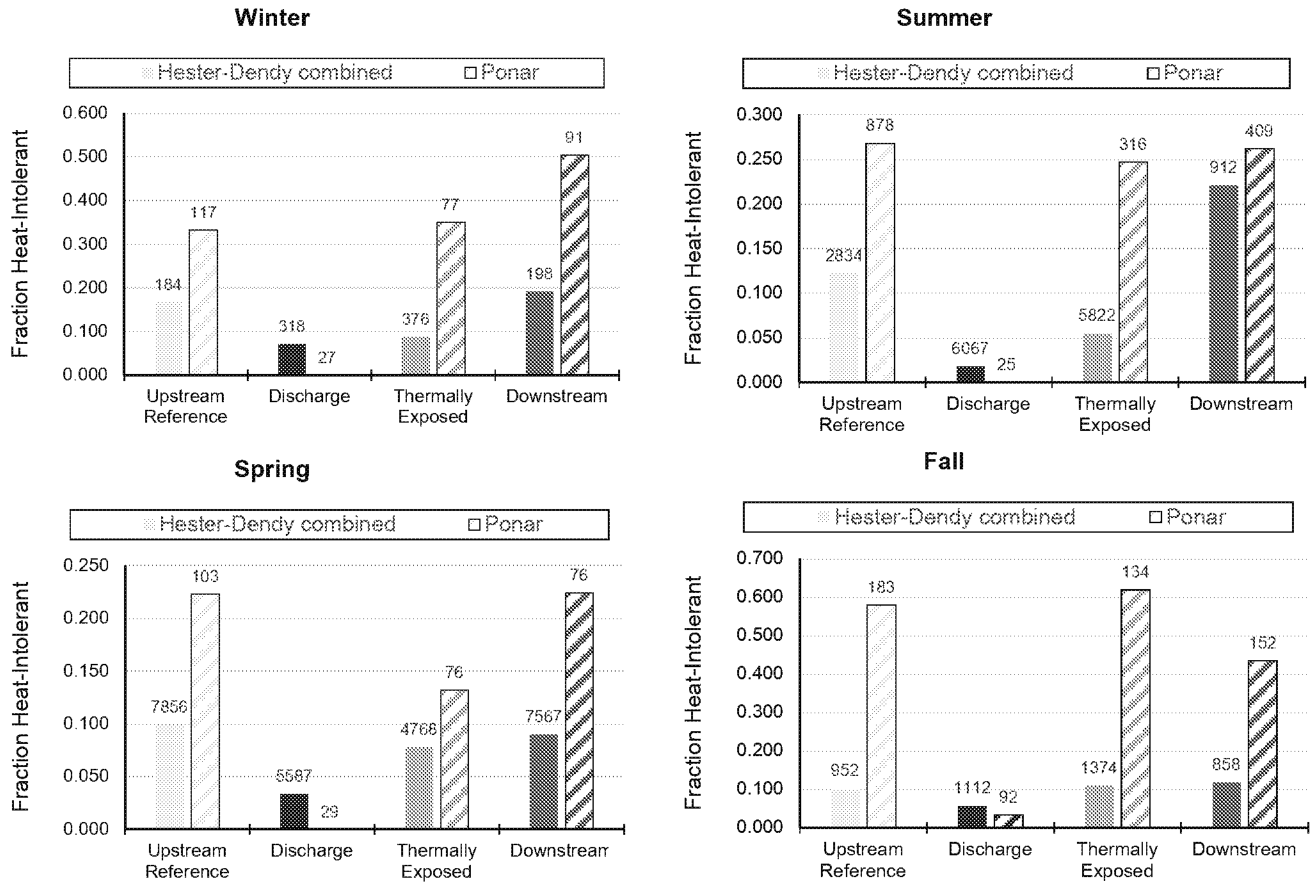


Figure 5-28 Fraction of EPT organisms that are heat-intolerant in Hester-Dendy (solid) and Ponar samples (hatched) in vicinity of the LEC, 2017-2018. Numbers over columns are the number of EPT organisms.

5.4.2.4 Overall Weight of Evidence

As with fish, a quantitative Weight-of-Evidence approach was used to evaluate the overall effects of the LEC's thermal plume on the benthic macroinvertebrate component of the BIC. In this analysis, a "standardized difference", essentially a t-statistic, was calculated for each ecological metric for each combination of gear and season comparing the Upstream Reference zone with the Thermally Exposed zone and with the Downstream zone. Each standardized difference was formulated so that it would have a negative value if consistent with harm, and a positive value if inconsistent.

$$Standardized\ Difference = X \frac{V_{TE\ or\ D} - V_{Upstream}}{\sqrt{se(V_{TE\ or\ D})^2 + se(V_{Upstream})^2}}$$

where

X = multiplier set to -1 or +1 so that the difference is negative if the change direction is consistent with harm

V = value of the metric

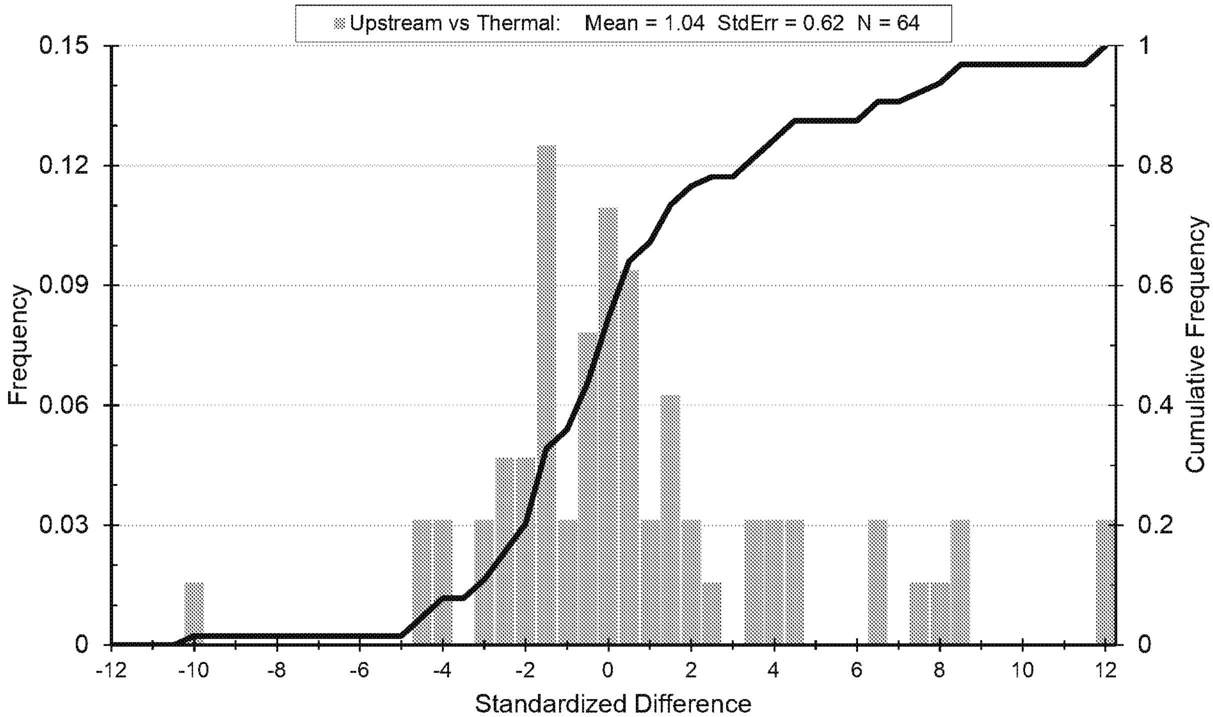
se(V) = standard error of the metric

Only metrics which had a directional (better vs worse) component were used. Metrics used were:

Metric	Basis	Directional
Abundance	Numbers	High better than low
Diversity ^0D (Family Richness)	Numbers	High better than low
Diversity ^1D (transform of H')	Numbers	High better than low
Diversity ^2D (Inverse Gini-Simpson)	Numbers	High better than low
Diversity ^3D (very abundant species)	Numbers	High better than low
EPT Species	Numbers	High better than low
Fraction EPT	Biomass	High better than low
Fraction EPT Heat Tolerant	Biomass	Low better than high

In a case where there is no effect of the thermal discharge, these standardized differences would be expected to have a distribution centered at 0, with approximately equal proportions positive and negative. If there were prior appreciable harm due to the thermal discharge, the distribution would be shifted toward negative values. In comparing the pattern of differences for the Thermally Exposed zone and the Downstream zone, the Thermally Exposed zone, where some effect of the discharge might be expected, would be more shifted toward the negative.

The overall pattern of differences across all the metrics examined is not consistent with harm from the thermal discharge (Figure 5-29). Distributions for both the Thermally Exposed zone and the Downstream zone compared to the Upstream Reference zone were shifted slightly positively from zero (mean for Thermally Exposed zone = 1.04 and for the Downstream zone mean = 0.55). The magnitude of the shifts were within 2 standard errors from 0, suggesting that the shifts may not be large enough to be biologically important. This is supported by the fact that the magnitude of the positive shift was greater for the Thermally Exposed zone than for the Downstream zone. If the LEC discharge were the primary cause of degraded conditions, any shift toward negative values should be greater in the Thermally Exposed zone than in the Downstream zone.



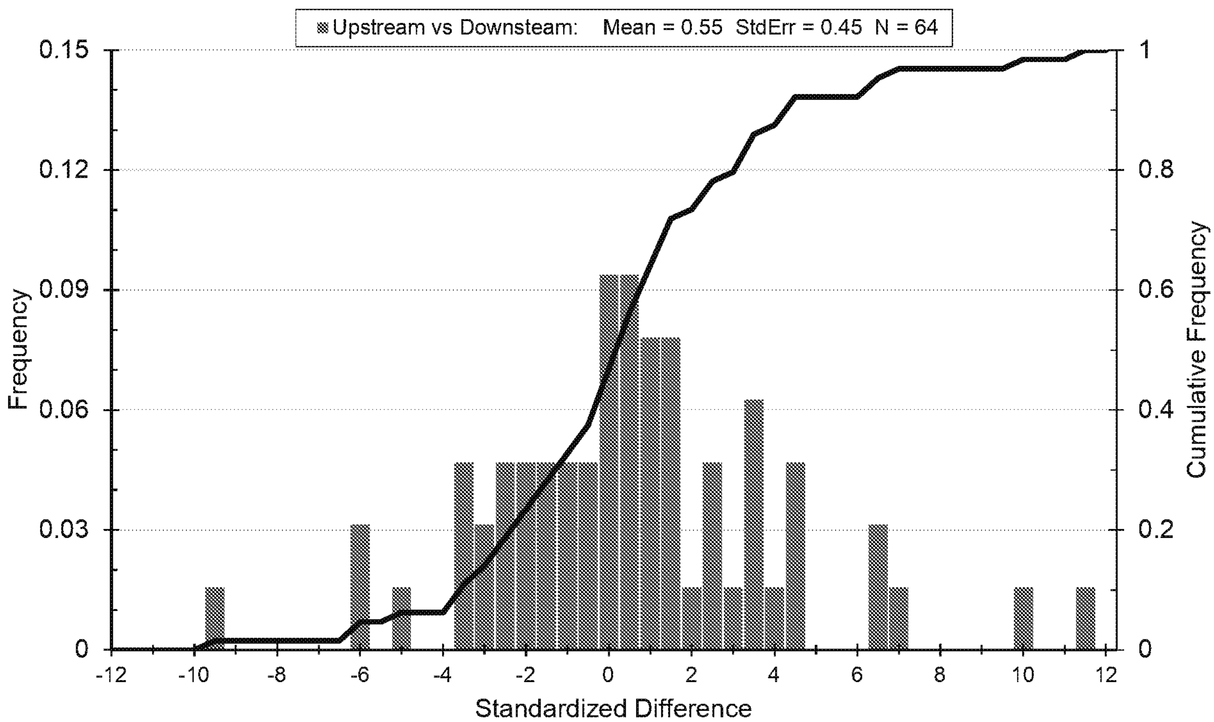


Figure 5-29 Distribution of standardized differences between ecological metrics for Upstream zone and Thermal zone (top) and Upstream zone and Downstream zone (bottom) over all gear and metrics for macroinvertebrate sampling.

5.5 TEMPORAL ANALYSIS

5.5.1 Introduction

Historical and current electrofishing data from corresponding sampling locations (Section 5.2.2) are available to determine whether any adverse trends in the fish assemblage over time exist. The available data were first evaluated for any methodological differences or biases that could affect the data comparison. The adverse effects, or appreciable harm, questions were then addressed using metrics including catch per unit effort (CPUE), biomass, diversity, community composition, and heat sensitive vs heat tolerant species.

5.5.2 Fish

When comparing ecological data collected over a period of nearly 40 years, it is important to assess whether the methodology may have changed in a way that could confound data interpretation. Although the electrofishing methodology was maintained the same in the 1980-1985, 1997-2002, and 2017-2018 surveys to the extent possible, the data suggested that different levels of attention to collecting small fishes occurred, particularly in 2017-2018. Electrofishing is a sampling method for collecting large fish that may be difficult to sample by other methods, and large fish, because they intercept a greater part of the electric field are more susceptible to being immobilized than are small fish. They are also more visible to the collectors and may be subject to a natural human bias to retrieve larger fish. For this reason, electrofishing data on small specimens may be less standardized than data for larger specimens (Reynolds 1984).

The length frequencies of the fish caught by electrofishing in the three surveys suggest differences in the degree of focus on collecting smaller fish (Figure 5-30 top). In the 1980-1985 surveys, relatively few fish less than 100 mm were collected. In contrast, the 1997-2002 surveys collected a large number of fish just less than 100 mm, and the 2017-2018 surveys collected a large number of fish 40-70 mm in length, with 40 percent of fish 100 mm or less (Table 5-10). Another signal that collection methods, with respect to the smaller fishes, is different is seen in the 16 species observed only in the ≤100 mm size class in the 2017-2018 sampling (plus red shiner which had only two individuals observed in the 1997-2002 survey). It is unlikely that these differences are solely due to actual differences in abundance or presence. In order to focus the analysis on fish that are actually the target of the electrofishing sampling effort, fish less than 100 mm in length were eliminated from the analysis.

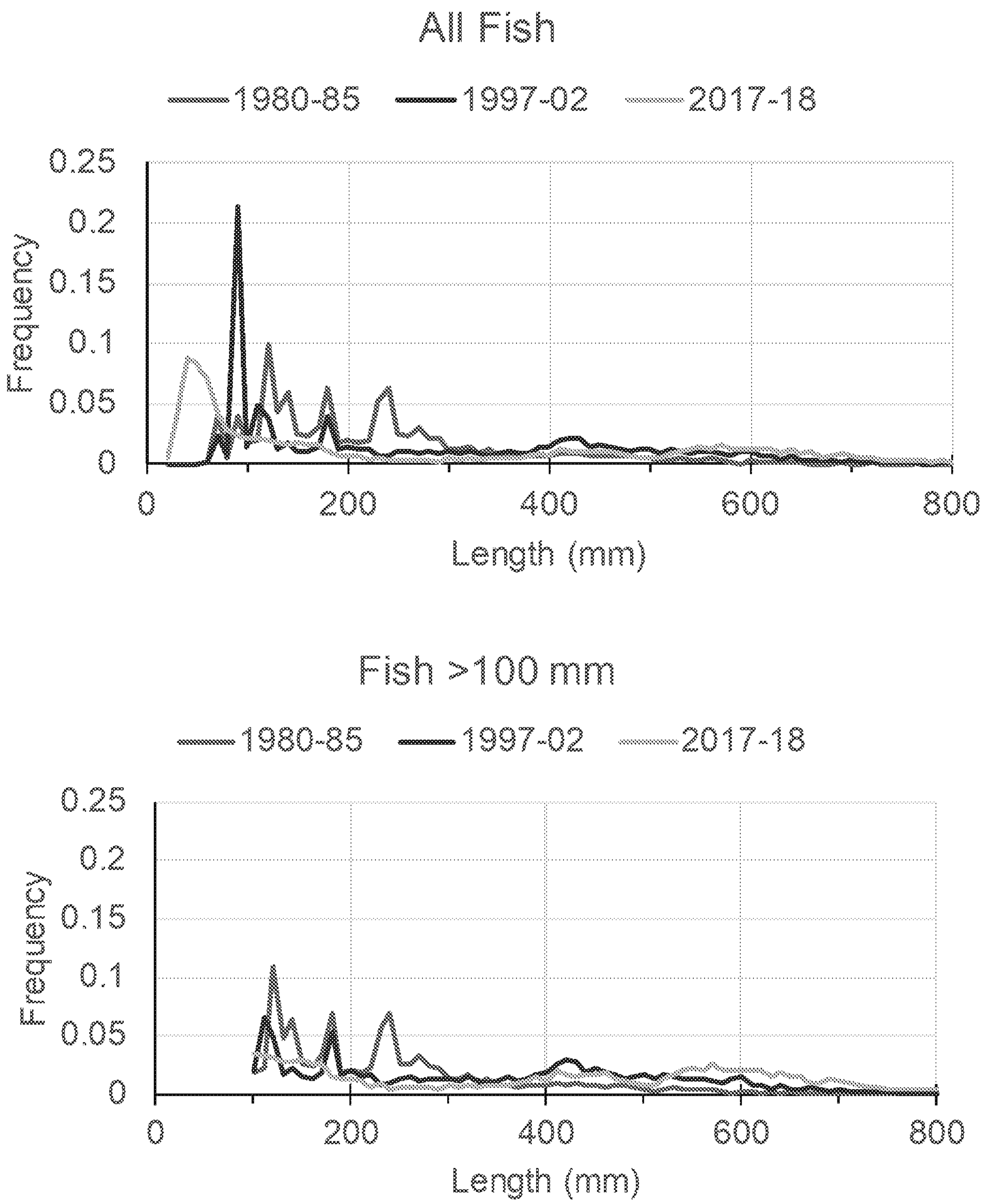


Figure 5-30 Length frequency of fish collected by electrofishing at the LEC in 1980-1985, 1997-2002, and 2017-2018. Top figure is all fish, bottom figure is subset to fish over 100 mm.

Table 5-10 Catch in electrofishing sampling in all seasons and zones combined at the LEC in 1980-1985, 1997-2002, and 2017-2018 of fish ≤100 mm and >100 mm. Highlighted cells indicate species collected only at lengths ≤100 mm and only in 2017-18 survey.

Common Name	1980-85		1997-02		2017-18		Total
	≤100	>100	≤100	>100	≤100	>100	
Gizzard shad	270	1593	975	1036	550	382	4806
Freshwater drum	17	258	7	188	29	418	917
River carpsucker	1	190	1	288	4	281	765
Common carp	0	120	0	473	0	149	742
Red shiner	0	0	2*	0	559	0	561
Blue catfish	0	54	0	133	8	364	559
Shortnose gar	0	121	0	131	3	224	479
Goldeye	4	156	0	103	31	116	410
Emerald shiner	0	0	0	0	408	0	408
Channel catfish	3	65	3	167	39	66	343
Longnose gar	0	40	0	41	1	227	309
Smallmouth buffalo	2	21	0	118	0	160	301
Flathead catfish	4	69	8	76	19	124	300
Silver carp	0	0	0	7	37	207	251
White bass	5	55	0	55	2	8	125
Channel shiner	0	0	0	0	107	0	107
Chestnut lamprey	0	47	0	8	0	2	57
Grass carp	0	1	0	8	0	43	52
Bluegill	5	5	2	4	17	14	47
Blue sucker	0	2	0	11	1	32	46
Bullhead minnow	0	0	0	0	42	0	42
Spotted bass	0	4	0	5	4	29	42
Striped bass x white bass	0	0	0	25	0	17	42
Bigmouth buffalo	0	9	0	15	0	16	40
Black buffalo	0	4	0	5	0	22	31
White crappie	0	18	1	1	0	6	26
Shovelnose sturgeon	0	2	0	1	0	20	23
Sand shiner	0	0	0	0	19	0	19
Brook silverside	0	0	15	0	2	0	17
Orangespotted sunfish	0	0	0	0	17	0	17
Mooneye	2	7	0	1	4	2	16
Shorthead redhorse	0	6	0	2	0	7	15
Skipjack herring	0	6	0	4	0	5	15
Bighead carp	0	0	0	8	0	6	14
Green sunfish	1	1	0	1	10	1	14
Quillback carpsucker	0	3	0	7	0	4	14

Common Name	1980-85		1997-02		2017-18		Total
	≤100	>100	≤100	>100	≤100	>100	
Black crappie	0	10	0	1	1	0	12
Sauger	0	7	0	2	0	3	12
Walleye	0	5	0	0	2	3	10
Largemouth bass	0	5	1	3	0	0	9
Golden redhorse	0	4	0	2	0	2	8
American eel	0	7	0	0	0	0	7
Shoal chub	0	0	0	0	7	0	7
Bluntnose minnow	0	0	0	0	6	0	6
Logperch	0	0	0	0	4	0	4
Longear sunfish	1	1	0	1	0	1	4
White sucker	0	1	0	3	0	0	4
Freckled madtom	0	0	0	0	3	0	3
Paddlefish	0	1	0	2	0	0	3
Smallmouth bass	0	3	0	0	0	0	3
Striped bass	0	2	0	1	0	0	3
Goldfish	0	0	0	0	1	1	2
Lake sturgeon	0	0	0	0	0	2	2
Suckermouth minnow	0	0	0	0	2	0	2
Central stoneroller	0	0	0	0	1	0	1
Fathead minnow	0	0	0	0	1	0	1
Largescale stoneroller	0	0	0	0	1	0	1
River shiner	0	0	0	0	1	0	1
Rock bass	0	1	0	0	0	0	1
Rosyface shiner	0	0	0	0	1	0	1
Sauger x Walleye	0	0	0	0	0	1	1
Silver chub	0	0	0	0	1	0	1
Silver lamprey	0	0	0	0	0	1	1
Silver redhorse	0	0	0	0	0	1	1
Spotted sucker	0	0	0	0	0	1	1
Total Individuals	315	2,904	1,015	2,937	1,945	2,968	12,084
Total Species	12	38	10	37	37	39	65
% ≤100 mm	10%		26%		40%		

* Highlighted even though 2 individuals were collected in 1997-2002 sampling.

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5.5.2.1 Overall Abundance

Temporal trends in fish abundance downstream of the LEC thermal discharge must be considered in context of the surrounding area. Summertime (July-Sep) numerical abundance in the Upstream Reference zone in the three surveys shows a declining trend in CPUE over time from 24 fish/20 min, to 19 fish/20 min, to 9 fish/20 min (Figure 5-31). In terms of fish biomass, the 1997-2002 surveys had the highest biomass (14 kg/20 min), with (12 kg/20 min) in the 1980-1985 survey and and later (8 kg/20 min) in the 2017-2018 survey.

In the area immediately downstream of the LEC discharge (Site 4 in early surveys and station 3-CXLD in the 2017-2018), a similar decline in CPUE was observed (Figure 5-32), matching the pattern seen upstream of the discharge. CPUE varied from 23 fish/20 min, to 11 fish/20 min, to 8 fish/20 min in the latest survey. Fish biomass in the three surveys varied from approximately 10 kg/20 min in 1980-1985, to 5 kg/20 min in 1997-2002, to 9 kg/20 min in 2017-2018.

Fish CPUE and biomass data from the Thermally Exposed zone during the summertime exhibit a similar temporal pattern to that from the Upstream Reference zone demonstrating that observed decreases in abundance over time are not the result of exposure to the LEC thermal discharge.

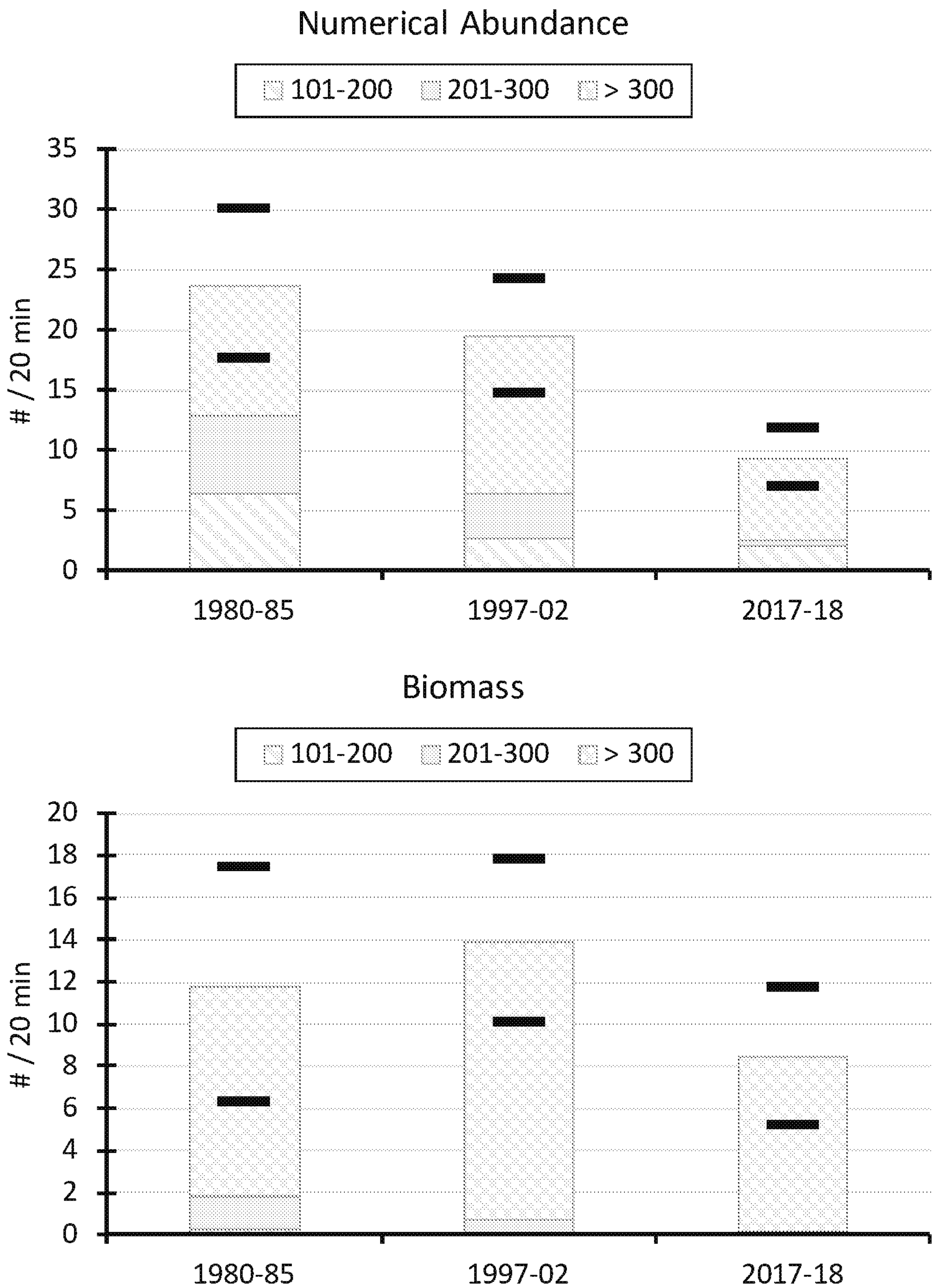


Figure 5-31 **Catch per 20 minutes of electrofishing sampling at the LEC in 1980-1985 and 1997-2002 at Site1, and 2017-2018 in Upstream Reference zone (OLD habitat in 2017-2018), in summer (Jul-Sep). Black horizontal bars are +/- one standard error from the total. Top figure is based on number of fish in each length class, bottom figure is based on biomass of fish in each length class (101-200 mm, 201-300 mm, and >300 mm).**

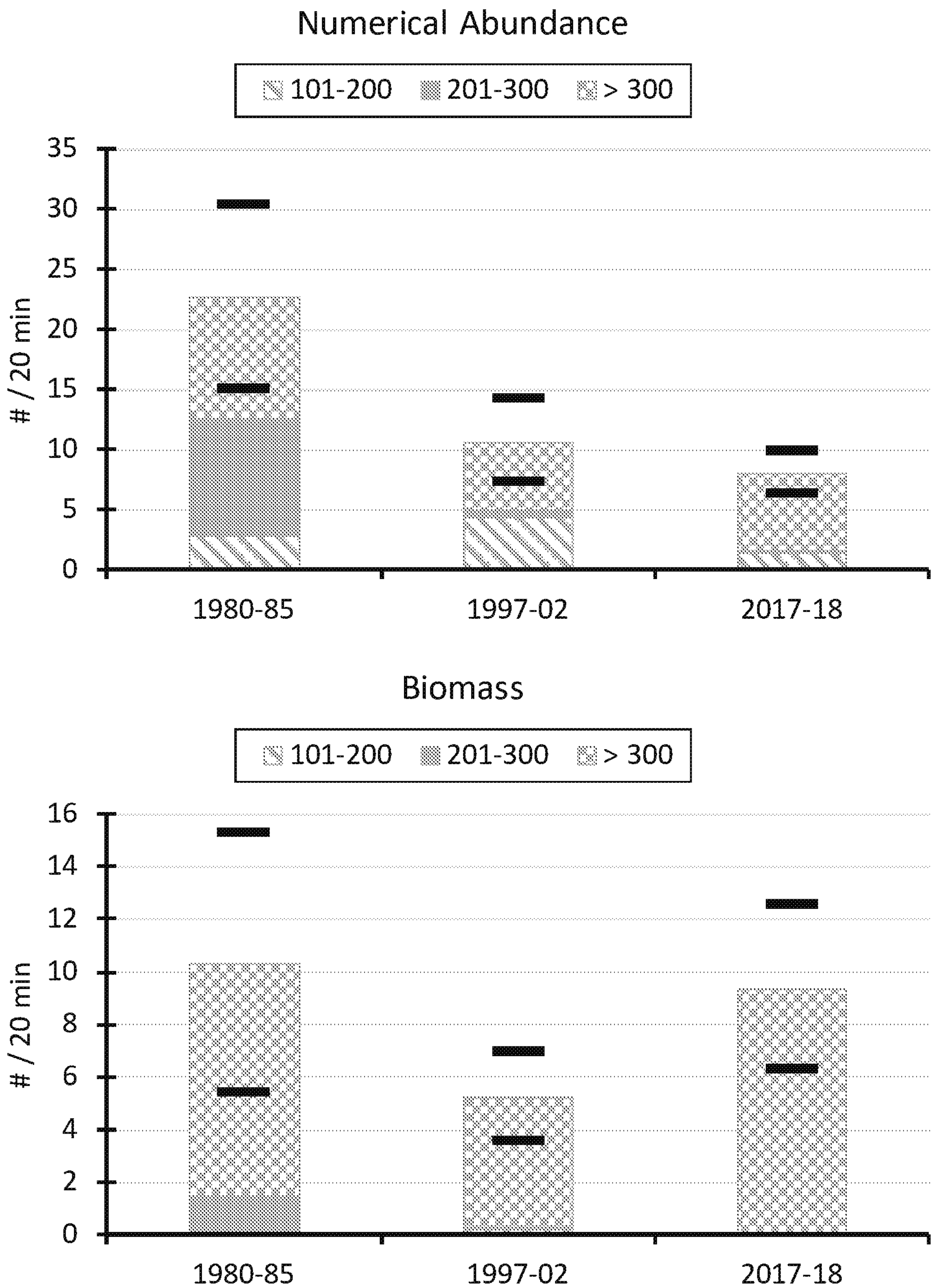


Figure 5-32 Catch per 20 minutes of electrofishing sampling at the LEC in 1980-1985 and 1997-2002 at Site1, and 2017-2018 in Thermally Exposed zone (CXLD habitat in 2017-2018), in summer (Jul-Sep). Black horizontal bars are +/- one standard error from the total. Top figure is based on number of fish in each length class, bottom figure is based on biomass of fish in each length class (101-200 mm, 201-300 mm, and >300 mm).

5.5.2.2 Community Characteristics

Diversity

For upstream reference areas (Site 1 in 1980-1985 and 1997-2002, and OLD habitat in the Upstream Reference zone in 2017-2018, summer) diversity profiles based on Hill numbers (Hill 1973) indicate very similar diversity in the earliest and latest sampling efforts, with reduced diversity in the intermediate survey (Figure 5-33). Species richness (number of species at 0 sensitivity to abundance) was slightly higher, 18 to 14, in the earliest sampling, but as sensitivity to abundance increased ($q > 0.5$), the two surveys were within 1 species. The last survey exhibited a diversity value of 10 equally abundant species (at $q = 1$), while the earliest survey had an equivalent diversity of 9 species. Effective species at $q = 2$ was approximately 8 and 7.5 respectively, and at $q = 3$ approximately 7 and 6.5. Diversity based on biomass exhibited qualitatively the same pattern as numerical diversity, however the number of effective species was slightly lower.

In the Thermally Exposed zone (Site 4 in 1980-1985 and 1997-2002, and CXLD habitat in 2017-2018, summer), species richness (number of species at 0 sensitivity to abundance) was higher, 17 to 13, in the earliest sampling (Figure 5-34). At higher sensitivity to abundance ($q > 0.5$), the most recent survey data had the highest diversity of the three surveys, and the 1997-2002 survey the lowest. Diversity based on biomass exhibited qualitatively the same pattern as numerical diversity, however the number of effective species was slightly lower.

The temporal trend in diversity in both the Upstream Reference and Thermally Exposed zones is similar indicating that exposure to the LEC discharge over time has not caused a decrease in diversity.

Dominance

The composition of the fish community in the Upstream Reference zone indicated domination by fishes classified as "rough" fish (see Table 5-5 for classification) (i.e. species that are not targeted by sport or commercial fishermen, and that as adults are too large for most piscivores to consume) in all three survey periods (Figure 5-35). The common groups in the rough fish category were gars, carp/goldfish, buffalo suckers (subfamily Ictiobinae), gizzard shad, and freshwater drum. Catfishes comprised the only common game fish, and there were few panfish. This community composition is not a representation of the entire fish community but, instead, reflects only larger fishes collected by the electrofishing survey methods. The composition changed little across the three surveys, except that rough fish were relatively more numerically abundant during the 1997-2002 survey (85 percent) than in the earlier (74 percent) or later (70 percent) surveys. Rough fish dominated the biomass in all surveys, ranging from 78 to 84 percent. Game fish were the second most dominant category.

The composition of the fish community in the Thermally Exposed zone, CXLD habitat, was also dominated by rough fish in the first and last surveys, but they generally were not as dominant ranging only from 34 to 72 percent of numerical abundance and 40 to 66 percent of biomass (Figure 5-36). Game/Commercial fish (mostly large catfishes and buffalos) were the other common category, with only small contributions from other categories. In the 1980-1985 and 1997-2002 surveys, the Game/Commercial category was the largest component of biomass (56 and 60 percent) but were only 34 percent of biomass in the 2017-2018 survey.

Based on the numerical diversity profiles and composition of the fish community in electrofishing samples from the Upstream Reference zones and in habitat CXLD in the Thermally Exposed zone in the summer, dominance of the different groups does not appear to have been adversely affected as a result of the LEC thermal discharge.

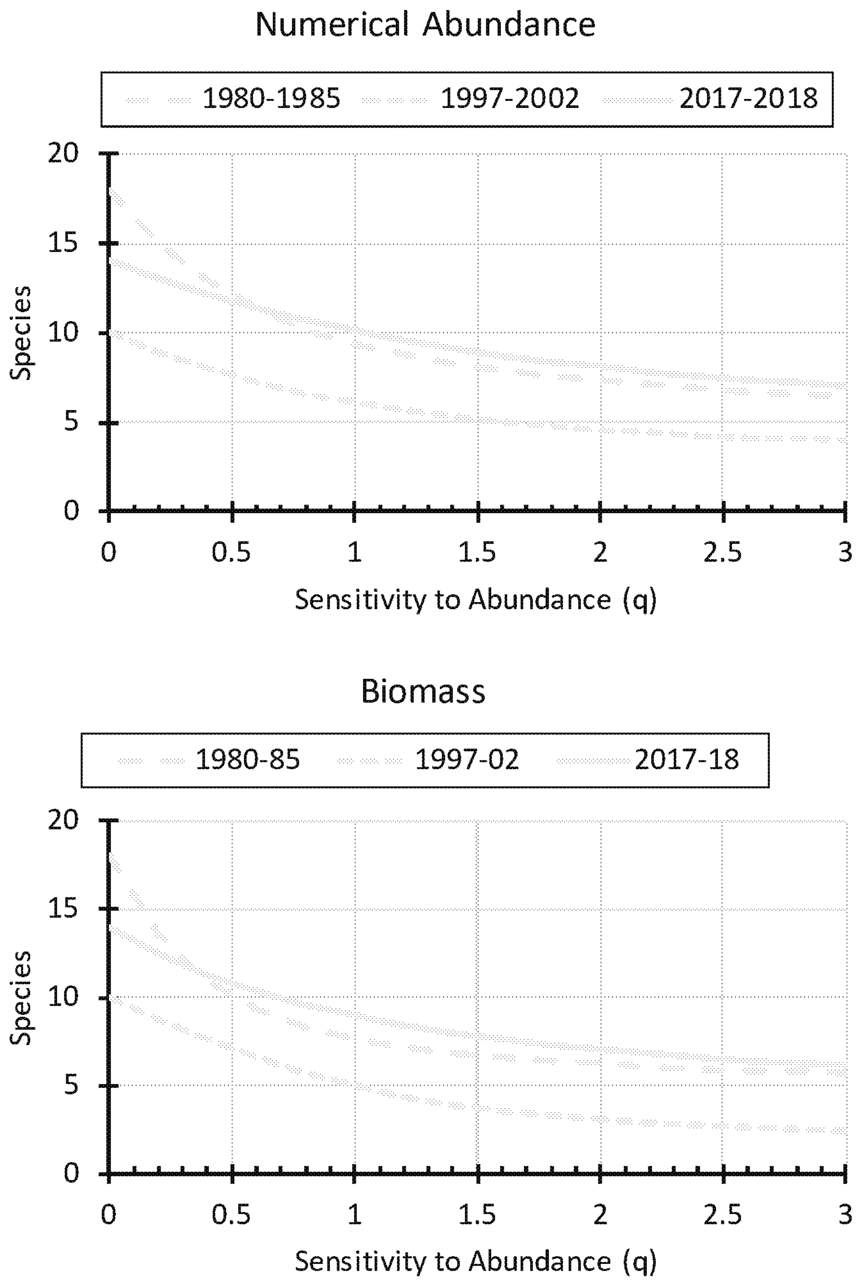


Figure 5-33 Diversity profiles based on Hill numbers for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in the Upstream Reference zone (OLD habitat in 2017-2018), in summer (Jul-Sep). Top figure is based on number of fish of each species, bottom figure is based on biomass of each species.

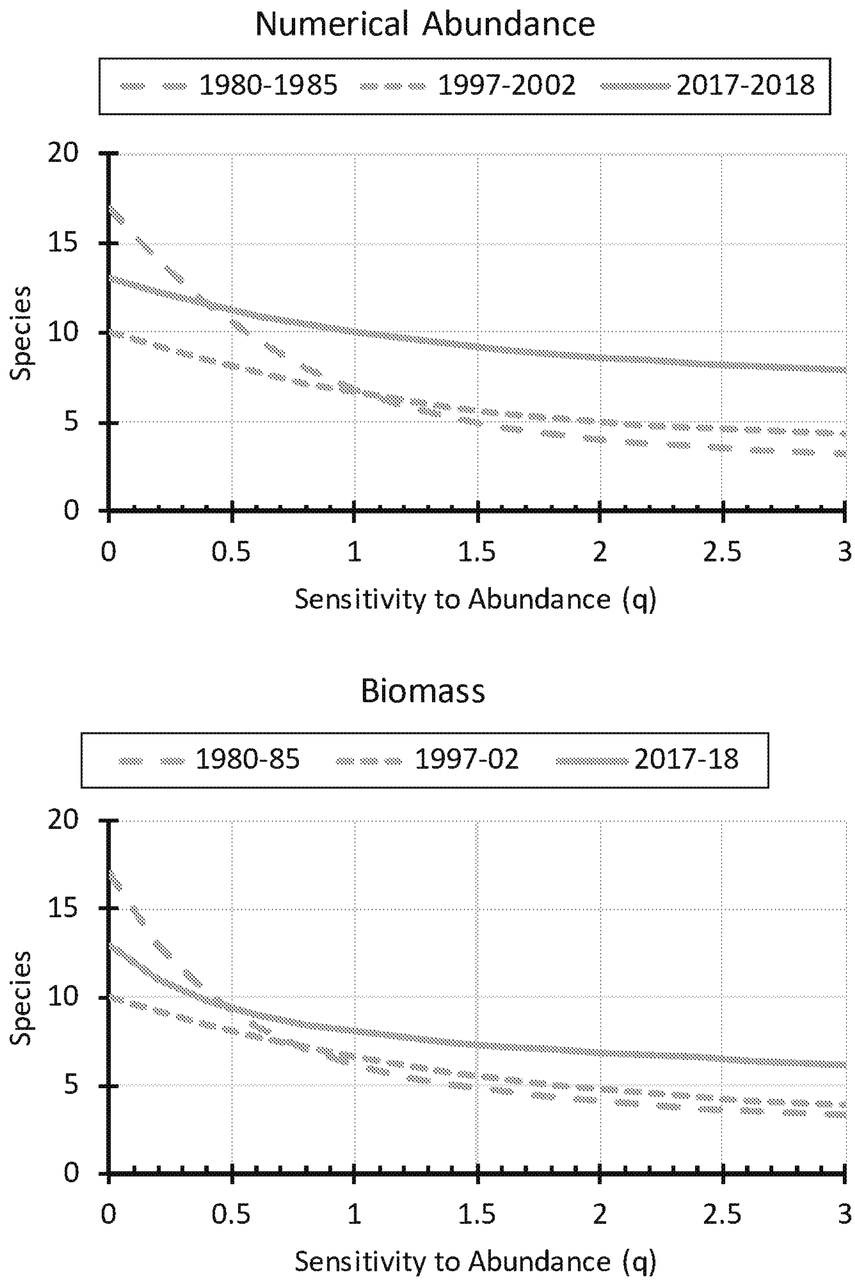


Figure 5-34 Diversity profiles based on Hill numbers for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in the Thermally Exposed zone (CXLD habitat in 2017-2018), in summer (Jul-Sep). Top figure is based on number of fish of each species, bottom figure is based on biomass of each species.

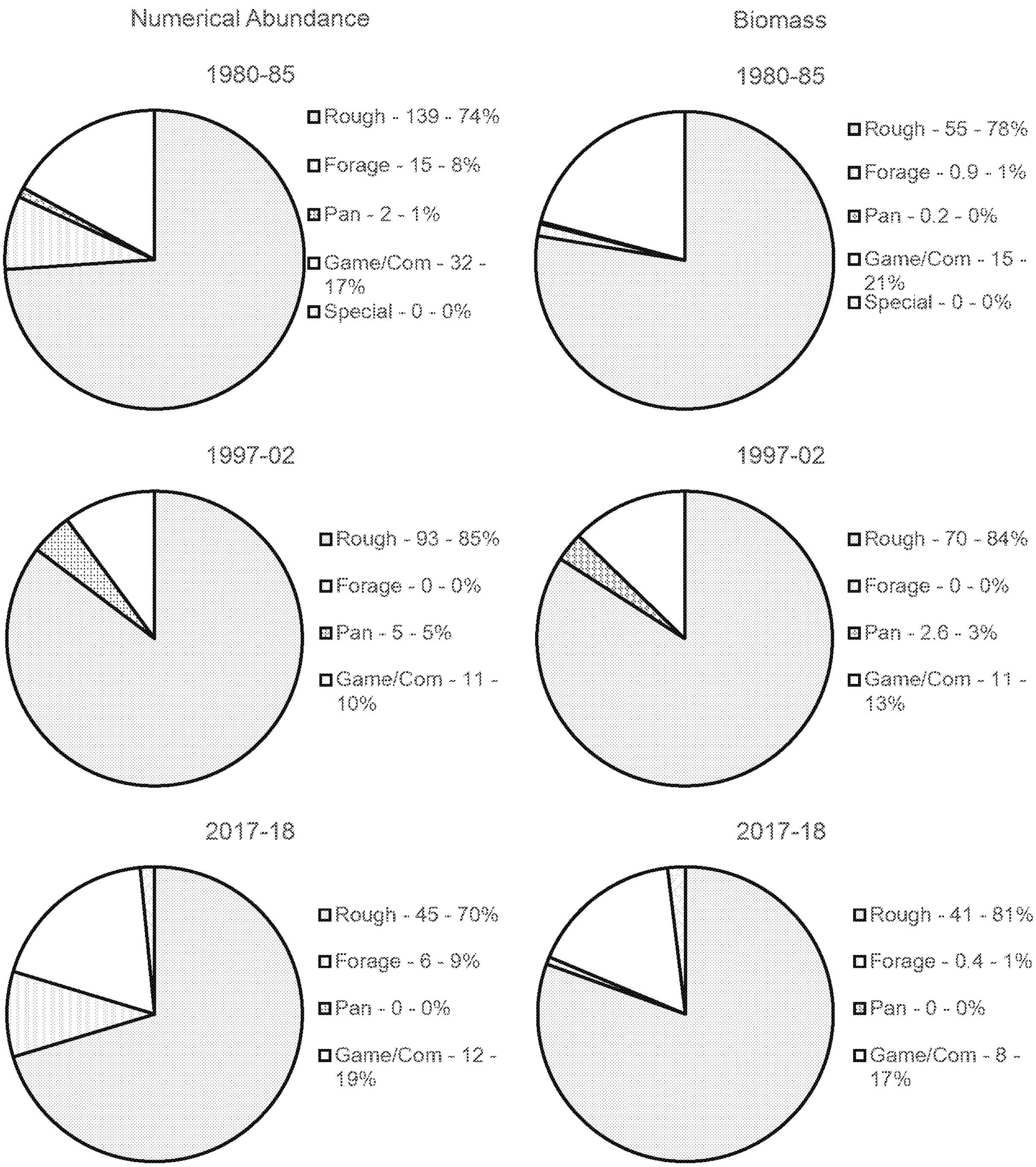


Figure 5-35 Fish community composition for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in Upstream Reference zone (OLD habitat in 2017-2018), in summer (Jul-Sep). Left side of figure is based on number of fish of each species, right figure is based on biomass of each species.

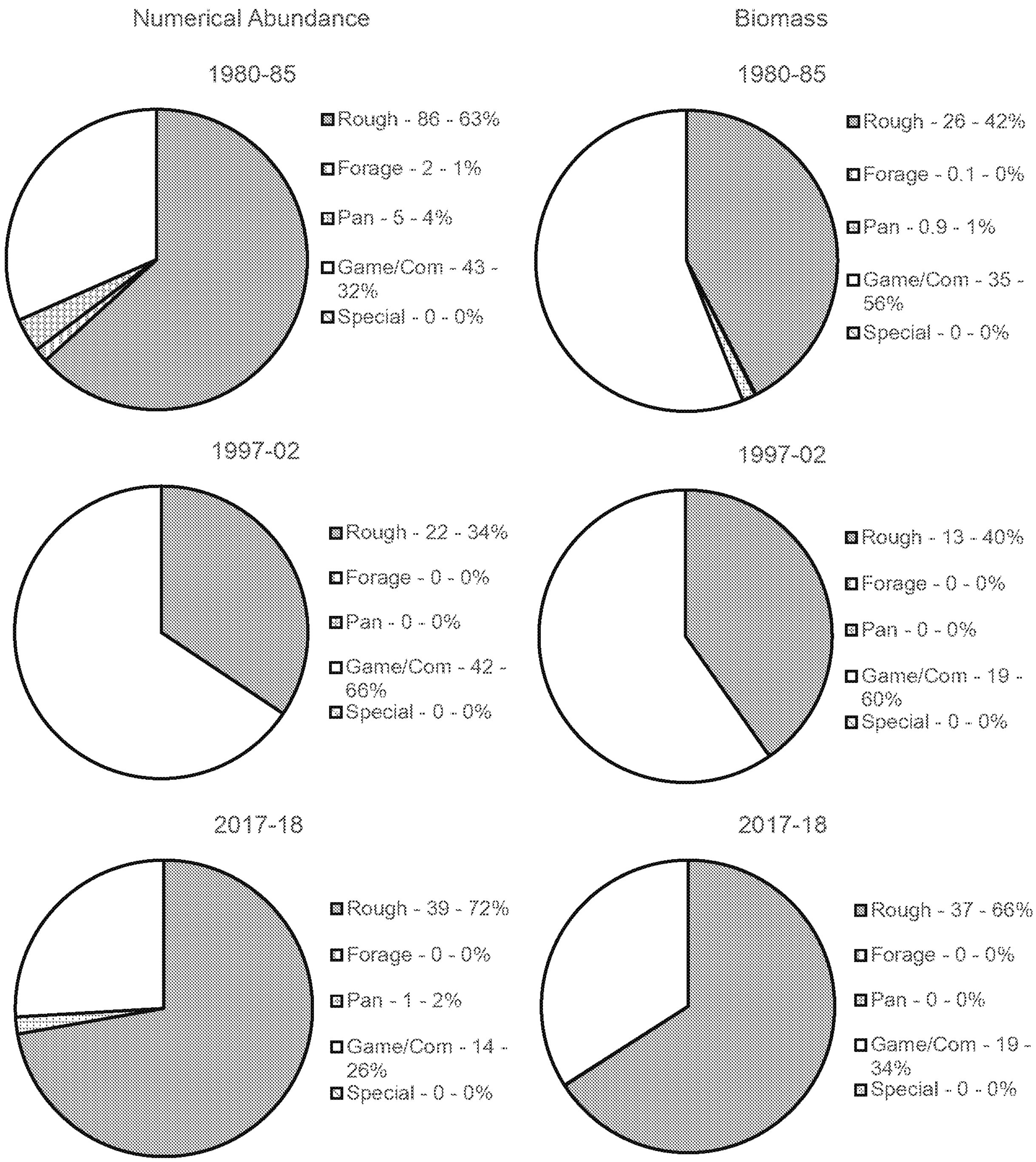


Figure 5-36 Fish community composition for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in Thermally Exposed zone (CXLD habitat in 2017-2018), in summer (Jul-Sep). Left side of figure is based on number of fish of each species, right figure is based on biomass of each species.

Dominance by Heat Tolerant Species

A sign that the LEC's thermal discharge is having an adverse effect would be if heat sensitive species would disappear or become less important members of the fish community, while heat tolerant species become more common. For purposes of this analysis, heat sensitive species are sauger, walleye, and their hybrid, mooneye, goldeye, and white crappie. Heat tolerant species are bighead carp, bigmouth buffalo, channel catfish, emerald shiner, flathead catfish, gizzard shad, longnose gar, river carpsucker, shortnose gar, silver carp, smallmouth buffalo (Appendix B Section B.2). As with the other questions, it is important to understand how this metric may be changing in the ecosystem independent of the thermal discharge.

In the Upstream Reference zone, the community was dominated by heat tolerant species comprising 58 percent to 70 percent of fish abundance and 31 percent to 74 percent of the biomass (Figure 5-37). There was no apparent temporal trend based on numerical abundance, but the fraction of thermally tolerant based on biomass declined from the first survey to the last.

Heat sensitive species comprised 0 percent to 8 percent by numbers, and 0 percent to 2 percent by weight of the fish collected, without any apparent temporal trend.

In the Thermally Exposed zone, the prevalence of heat tolerant species was higher, ranging from 68 percent to 91 percent by numbers, and 37 percent to 78 percent by biomass, without any evident temporal trend (Figure 5-38). Highest prevalence of tolerant species occurred in the 1997-2002 surveys. Heat sensitive species were very scarce in this zone in the summer, with maximum observed prevalence of 2 percent and there is no temporal increase in heat tolerant species, and no observed temporal decline in heat sensitive species. This analysis demonstrates that the LEC's thermal discharge has not caused a change in the relative abundance of heat tolerant or heat sensitive species.

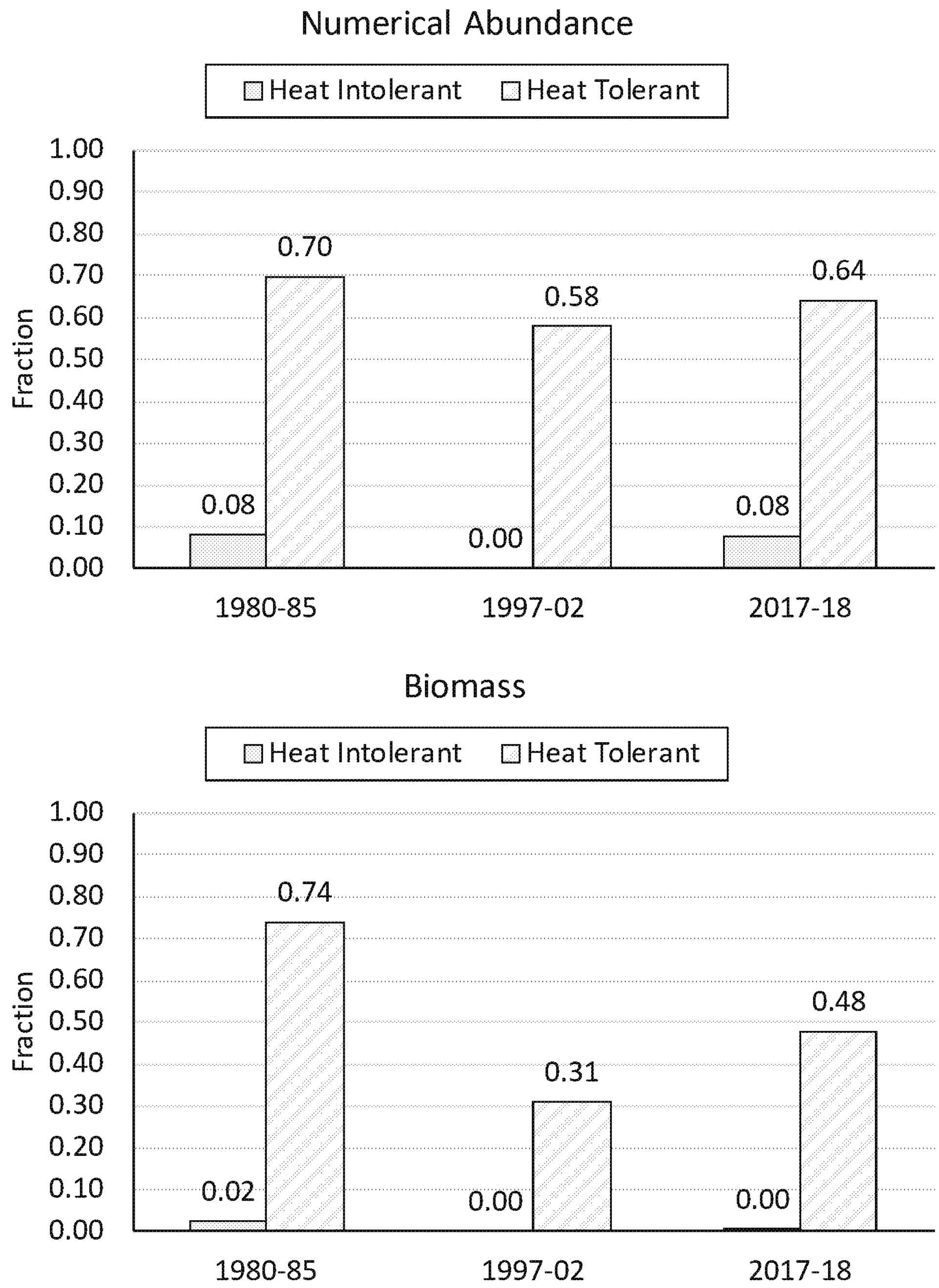


Figure 5-37 Fraction of heat-tolerant and heat-intolerant species for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in Upstream Reference zone (OLD habitat in 2017-2018), in summer (Jul-Sep). Top figure is based on numerical abundance, bottom figure is based on biomass.

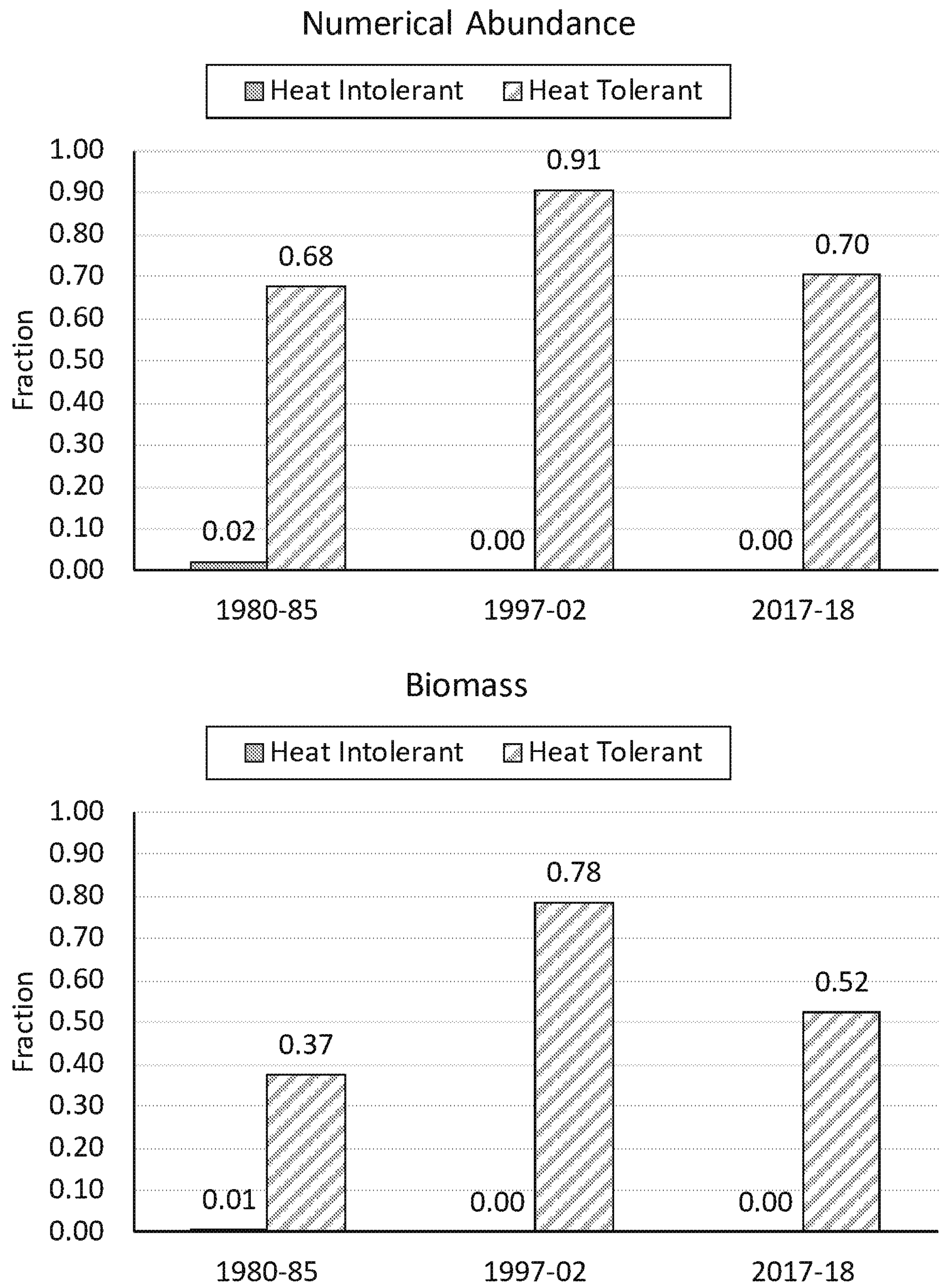


Figure 5-38 Fraction of heat-tolerant and heat-intolerant species for electrofishing sampling at the LEC in 1980-1985, 1997-2002 at Site 4, and 2017-2018 in the Thermally Exposed zone (CXLD habitat in 2017-2018), in summer (Jul-Sep). Top figure is based on numerical abundance, bottom figure is based on biomass.

5.5.2.3 Overall Weight of Evidence

In order to assess the overall weight of evidence in an objective quantitative manner, a "standardized difference", essentially a t-statistic, was calculated for each ecological metric for each combination of season and sampling zone comparing changes between the 1980-1985 survey and the 2017-2018 survey. Each standardized difference was formulated so that it would have a negative value if consistent with harm, and a positive value if inconsistent.

$$Difference = X \frac{V_{2017-18} - V_{1980-85}}{\sqrt{se(V_{2017-18})^2 + se(V_{1980-85})^2}}$$

where

X = multiplier set to -1 or +1 so that the difference is negative if the change direction is consistent with harm

V = value of the metric

se(V) = standard error of the metric

In a case where there is no temporal change between surveys, these standardized differences would be expected to have a distribution centered at 0, with approximately equal proportions positive and negative. If there were prior appreciable harm due to the thermal discharge, the distribution for the Thermally Exposed zone would be shifted toward negative values, in comparison to the distribution for the Upstream Reference zone.

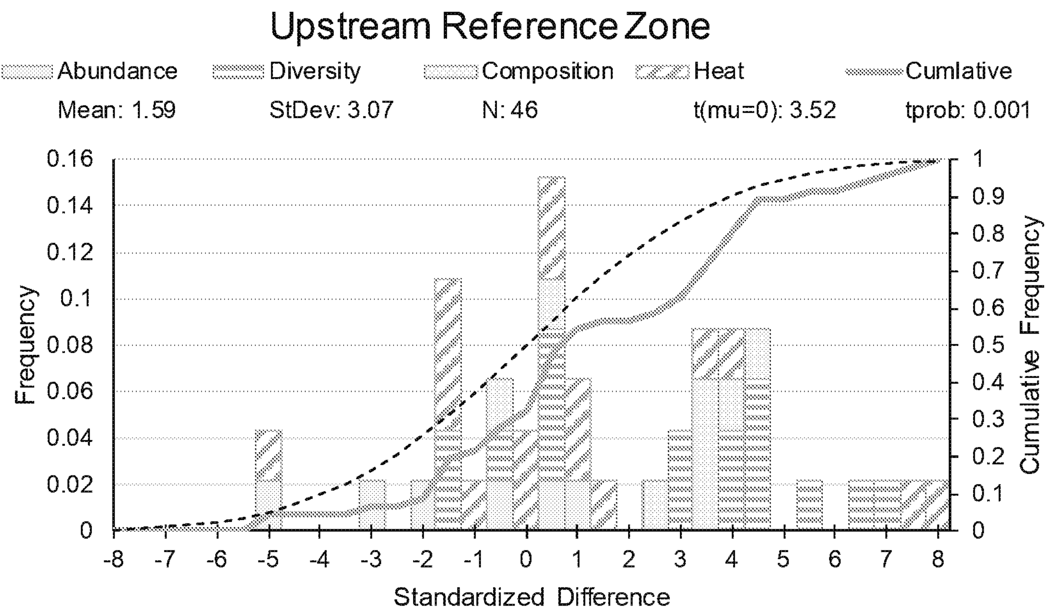
Only metrics which had a directional (better vs worse) component were used. Metrics used were:

Metric	Basis	Directional
Abundance	Numbers	High better than low
Abundance	Biomass	High better than low
Diversity ^0D (Species Richness)	Numbers	High better than low
Diversity ^1D (transform of H')	Numbers	High better than low
Diversity ^2D (Inverse Gini-Simpson)	Numbers	High better than low
Diversity ^3D (very abundant species)	Numbers	High better than low
Fraction Non-Rough	Numbers	High better than low
Fraction Non-Rough	Biomass	High better than low
Fraction Heat Intolerant	Numbers	High better than low
Fraction Heat Intolerant	Biomass	High better than low
Fraction Heat Tolerant	Numbers	Low better than high
Fraction Heat Tolerant	Biomass	Low better than high

For the Upstream Reference zone, the distribution of standardized differences had a mean of 1.59, standard error of 0.45, and median of 0.93 (Figure 5-39 top). Differences based on abundance metrics appeared to be more frequently negative, while those based on diversity and composition were more frequently positive. As a whole, the differences suggest an improvement of the fish community between 1980-85 and 2017-18.

The distribution of differences in the Thermally Exposed zone had a mean of 1.12, standard error of 0.47, and median of 0.56 (Figure 5-39 bottom). As in the Upstream Reference zone, abundance metrics were generally negative while diversity and composition metrics were usually positive.

The temporal trend analysis indicates that the fish community in the Thermally Exposed zone changed in ways similar to those in the Upstream Reference zone indicating no adverse effects from exposure to the LEC thermal discharge over time. A Kolmogorov-Smirnov test that the two distributions of standardized differences were different was not significant ($KS = 0.087$ $p = 0.490$).



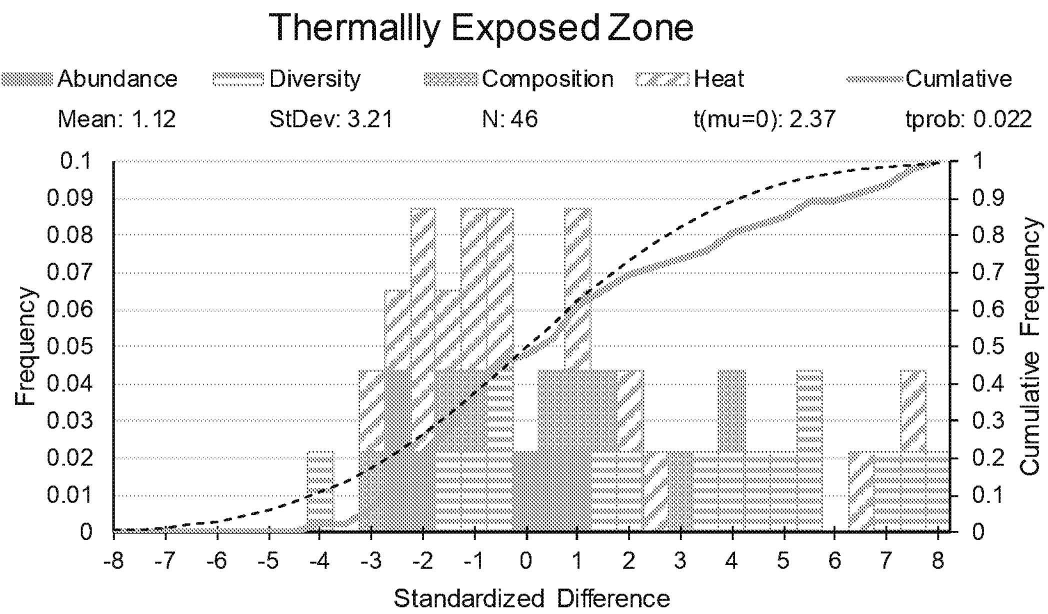


Figure 5-39 Standardized differences of ecological metrics between 1980-1985 and 2017-2018 for the Upstream reference zone (top) and Thermally Exposed zone (bottom) based on electrofishing data. Dashed line indicates cumulative normal distribution with mean = 0.

6. PREDICTIVE ASSESSMENT

A "Predictive Assessment" as part of a § 316(a) Demonstration evaluates potential effects of a thermal discharge using characteristics of the thermal plume, together with reported effects of thermal exposures on the aquatic organisms of interest. In the Guidance Manual (USEPA 1974, 1977), this type of approach falls under the category of a Type II Demonstration. In the overall process of evaluating the BIC protection, a predictive assessment serves as a complement to a "No Prior Appreciable Harm" assessment that was the focus of the previous section in that it allows consideration of:

- Thermal discharge conditions not frequently encountered at the facility;
- Biological functions not directly observed in the field study; and,
- Species not collected in sufficient numbers to permit a retrospective assessment of effects (e.g., rare, threatened or endangered species).

A predictive assessment is typically conducted in three steps:

1. Predicting the likely temperature exposures resulting from the facility's thermal discharge;
2. Selecting RIS that best reflect the biotic components of the aquatic community not determined to be low potential impact (Section 4); and,
3. Determining the potential effects of the predicted thermal exposures to each RIS.

Each of these three steps is discussed with specific reference to the LEC thermal discharge in more detail below.

6.1 THERMAL EXPOSURES FROM LEC DISCHARGE

As noted in Section 2, the LEC thermal discharge has not violated the NPDES permit limit for temperature (TDP $\leq$ 0.95) since this limit was adopted in 2017. Further, retrospective calculation of daily TDP over the 17-year period (2002 – 2018) revealed that the TDP was less than 0.95 more than 99 percent of the time. Hence, it is reasonable to presume that the Designated Uses of the LMOR in the vicinity of the LEC (including Livestock & Wildlife and Warm Water Habitat) are being protected.

6.1.1 Modeling of the LEC Thermal Plume

The focus of this predictive assessment is on the relatively rare events (<1 percent of the time) when the TDP limit is greater than 0.95 necessitating this variance request. The potential thermal exposures during these rare events were assessed using a three-dimensional hydrodynamic model (FLOW-3D) of the LMOR in the vicinity of the LEC (Flow Science 2016). FLOW-3D belongs to a family of models known as Computational Fluid Dynamics (CFD) Models. The system to be simulated posed challenges in that it was necessary to address both the nearfield jet-induced mixing of the discharge in the river, as well as the far-field ambient mixing and heat transport that occurs downstream in the river. CFD represents the state of the art in hydrodynamic simulation.

Application of FLOW-3D to the LMOR involved construction of a computational mesh or grid, which is effectively a numerical description of the actual physical system. Once constructed, the model enables the user to simulate the three-dimensional mixing of the LEC thermal discharge in the Missouri River for particular combinations of flow and temperature in both the river and the discharge. Thus, the inputs to any individual simulation include the LMOR flow rate and temperature as well as the LEC discharge rate and temperature, and the output from the model is the three-dimensional temperature distribution in the river throughout the model domain for a defined distance downstream of the LEC discharge.

A model domain extending from approximately 0.75 river miles upstream of the facility discharge to a point 3.5 river miles downstream of the discharge was selected. Based on evaluation of temperature monitoring data in the river and subsequent model simulations, the spatial extent chosen was more than sufficient to evaluate compliance with the water quality criteria for temperature. In order to examine conditions further downstream in the river, some simulations used a model domain extending 7.65 river miles downstream.

FLOW-3D relies on a detailed description of the physical processes and physical data for the system being simulated. There are no model coefficients that must be calibrated to make the model "fit the data." Other simulation models systematically rely on fine-tuning of model coefficient values to minimize the difference between observed and predicted results. Consequently, there is no need in this instance for a calibration step. FLOW-3D, once constructed for the system under study, can be used to simulate the system, and the FLOW-3D output can be directly compared to known system data as a validation of its ability to simulate the system. Six independent temperature data collection surveys conducted in the river over a 14-year period (years 2003 to 2016) and a wide range of flow and temperature conditions in both the river and the discharge were used to validate the model. Rigorous statistical methods to compare model output against actual data found excellent agreement between the model and the data, demonstrating the model's validity to simulate this system. More information on this model and its application to LEC's thermal discharge are provided in Kleinfelder (2016, 2017a, and 2017b).

The validated model for the LEC's thermal plume provides a valuable tool that can assess system response for any combination of the key system inputs, i.e., flow and temperature in both the river and in the discharge. This model was initially used to develop the TDP-based thermal limit adopted in the LEC's NPDES permit in 2017 as discussed in Section 2.4 and 2.5. This thermal limit assures compliance with $MWQS_t$ at the edge of the allowable mixing zone.

Beyond its use to develop the TDP limit, this validated model provides important information on thermal exposures in the river during actual historic events to be used as part of the predictive biothermal assessment. Specifically, this model provides:

- Estimates of the longitudinal, horizontal, and vertical distribution of elevated water temperatures downstream of the LEC's discharge; and,
- Temperature exposure profiles for organisms that might drift through the thermal plume using FLOW-3D's ability to track flow path for individual particles.

Model results using data from two days reflecting the most extreme conditions over the 17-year data record during the most biologically active periods of the year were selected for this assessment. Actual river and discharge flows and temperatures from June 22, 2006 ("June Model') were used in the model reflecting the most extreme conditions during the spring spawning and nursery period. Similarly, actual river and discharge flows and temperatures from July 21, 2006 ("July Model") were used reflecting the most extreme conditions during the high temperature period in summer. It is helpful to note that the TDP value was calculated to be less than 0.95 on June 22, 2006, while the calculated TDP value on July 21, 2006 was 2.65, the highest daily value calculated across the 17-year data record. These individual dates had the most extreme conditions across the more than 6,000 days of available data and occurred during an exceedingly hot and dry period in the Missouri River valley.

6.1.2 Spatial Distribution in Temperatures

In both cases, the model demonstrated a rapid mixing of the heated effluent with the much larger volume of water coming from upstream (typically 40 to 50 times discharge flow), yielding a rapid decline in temperatures following initial dilution. The resulting plume hugged the south shore immediately downstream of the discharge with the plume extending only part way across the

LMOR (Figure 6-1 and Figure 6-2). For the June Model, temperatures above 90°F were limited to areas along the south shore of the river within 1 mile of the discharge. For the July Model, temperatures above 90°F were limited to areas in the southern half of the river within about 5.5 miles of the discharge. Turbulence within the LMOR results in a high degree of mixing vertically, although plume temperatures and width were slightly lower near the bottom close to the point of discharge owing to plume buoyancy (Figure 6-3 and Figure 6-4).

Analysis of the temperature distributions in areas downstream of the LEC's discharge revealed that the volumes and surface areas of the LMOR encompassing specific temperatures show almost identical patterns on both dates modeled. Based on the June Model, selected to reflect worst-case spawning and nursery conditions, more than 97 percent of the volume and area within the model boundaries experienced temperatures less than or equal to 90°F while less than 1 percent experienced temperatures in excess of 100°F (Figure 6-5 top). Based on the July Model, selected to reflect worst-case summer conditions, temperatures were naturally higher (ambient, background temperature was 88.83°F) with slightly more than 50 percent of the volume and area of the expanded model boundaries experienced temperatures less than or equal to 90°F, but still less than 1 percent experienced temperatures in excess of 100°F (Figure 6-5 bottom).

6.1.3 Exposures of Drifting Organisms

Organisms with no or limited swimming ability can be carried by the river currents into the vicinity of the LEC and potentially exposed to elevated temperatures from the LEC's discharge. Organisms that fall into this category include eggs and larvae of fish that use the river's currents as a natural dispersal mechanism. To address the exposures to elevated temperatures from the LEC's thermal plume for these organisms, the Flow-3D model was used to track individual particles as they transit the section of the LMOR potentially influenced by the thermal discharge. In this modeling effort, hypothetical neutrally buoyant particles were released every 45 feet across the LMOR and at four depths from the bottom to the surface at a point just upstream of the LEC's point of discharge. The model software then tracked each of these particles as they were transported downstream by river currents and calculated the temperatures to which each was exposed every 10 seconds after release. These particles should reflect the transport of passive organisms through the area potentially exposed to the LEC's thermal plume.

In the June Model, the background temperature was 83.58°F and only 13 of the 56 particles released (23 percent) were exposed to temperatures in excess of the $MWQS_t$ for temperature (Figure 6-6). In the July Model, the background temperature was higher at 88.88°F but only 9 of the 51 particles released (<18 percent) were exposed to temperatures in excess of the $MWQS_t$ for temperature. In both models, exposed particles were restricted to those released in areas near the southern shore of the river.

Tracking the elevated temperatures for individual particles through time can provides information on the magnitude and duration of potential exposures experienced by passively drifting organisms on both modeled dates (Figure 6-7). First, the particles released across the cross-section of the river experienced temperature increases of only 2 degrees F or less. Second, only 10 percent of the particles experienced temperature increases of 8 degrees F or more. Finally, maximum temperature elevations rapidly decreased by more than 70 percent within 10 minutes of discharge. This rapid temperature decline can be attributed to turbulence and the high volume of river flows compared to plant discharge flows within the LMOR leading to rapid mixing. This rapid mixing helps to limit exposure of passively transported organisms to elevated temperatures from the LEC's thermal discharge.

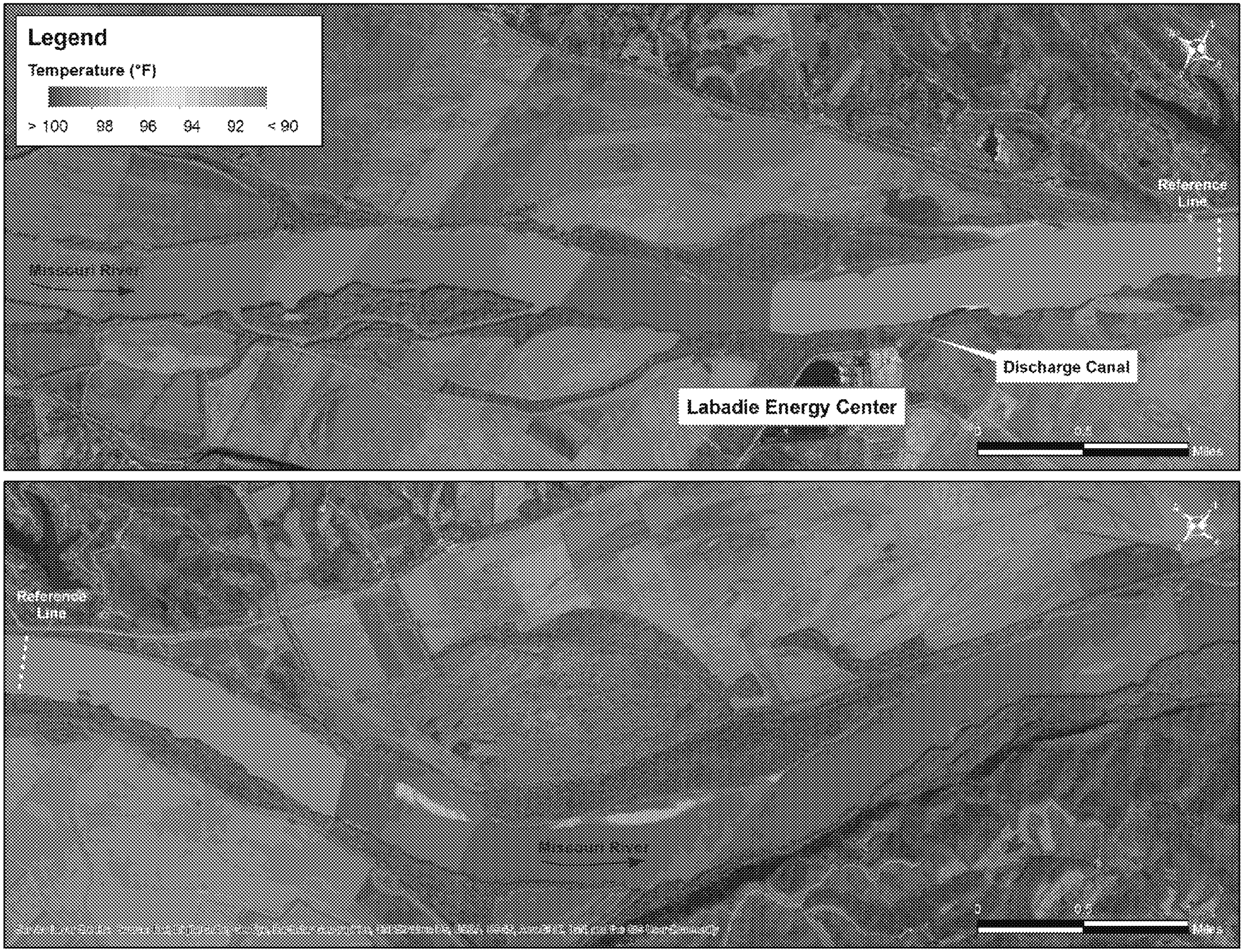


Figure 6-1 Spatial distributions of elevated temperatures from LEC's thermal discharge based on modeling of conditions from June 22, 2006.

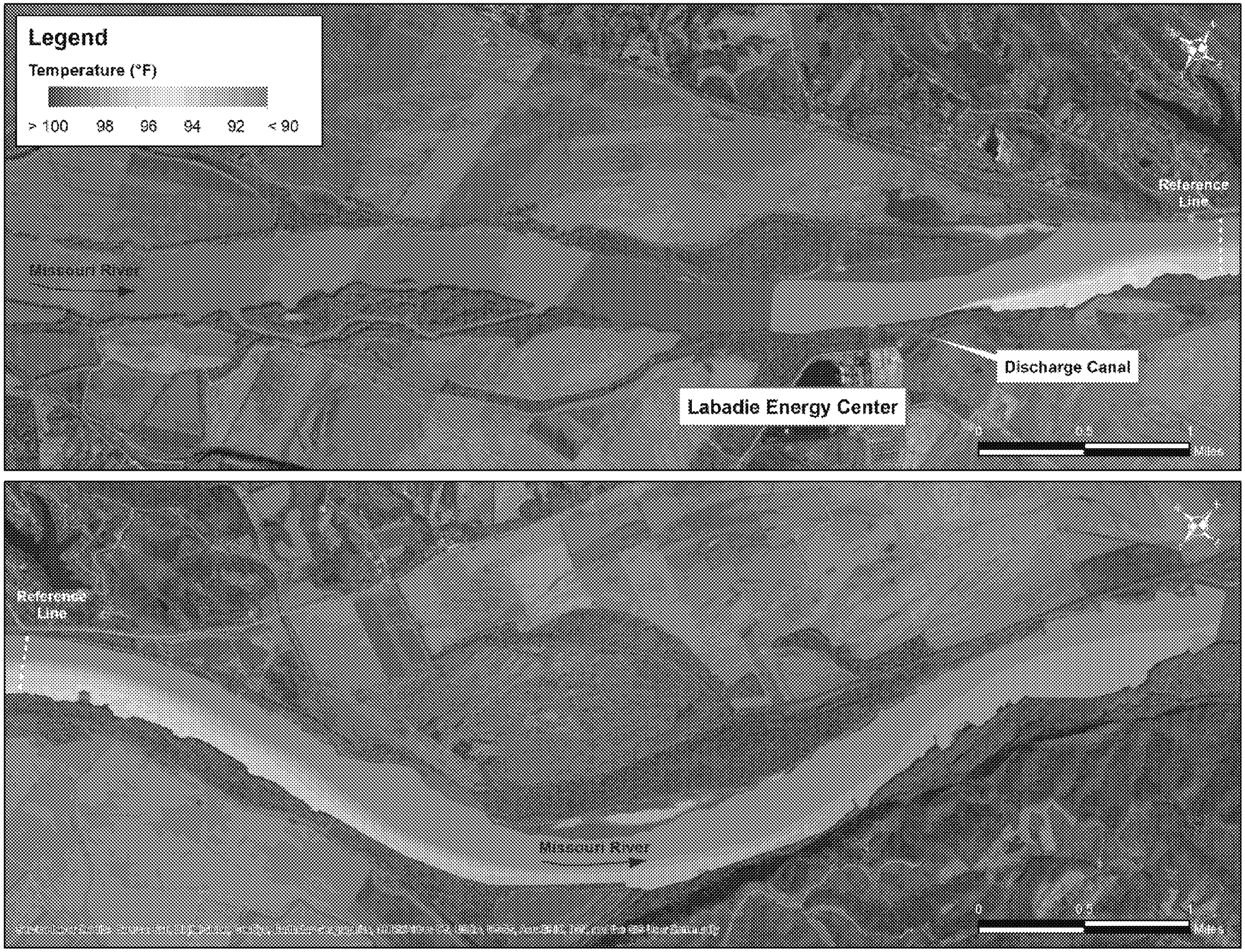


Figure 6-2 Spatial distributions of elevated temperatures from LEC's thermal discharge based on modeling of conditions from July 21, 2006.

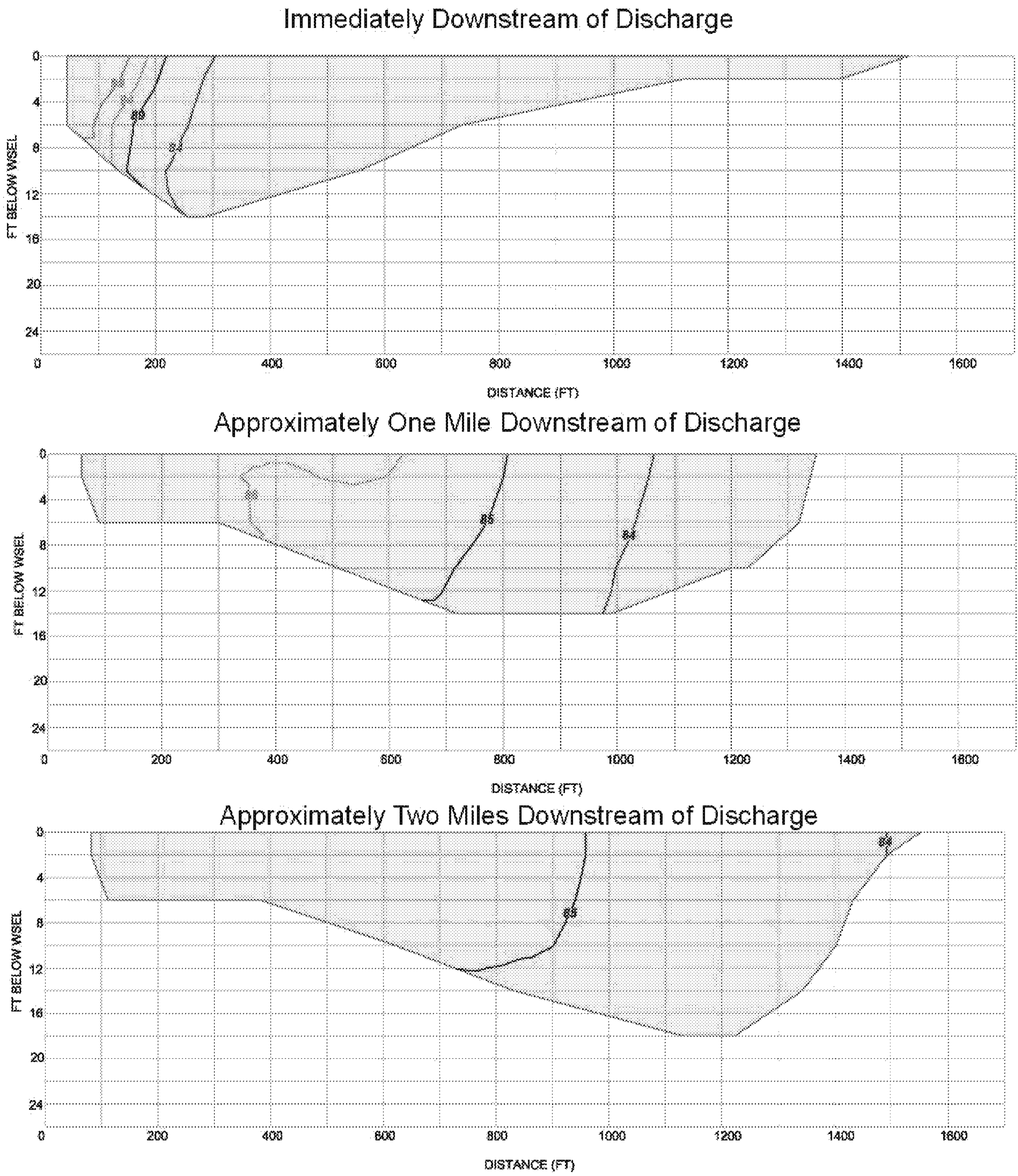


Figure 6-3 Distribution of elevated temperatures from LEC's thermal discharge in cross-section at three separate locations in the LMOR based on modeling of conditions from June 22, 2006.

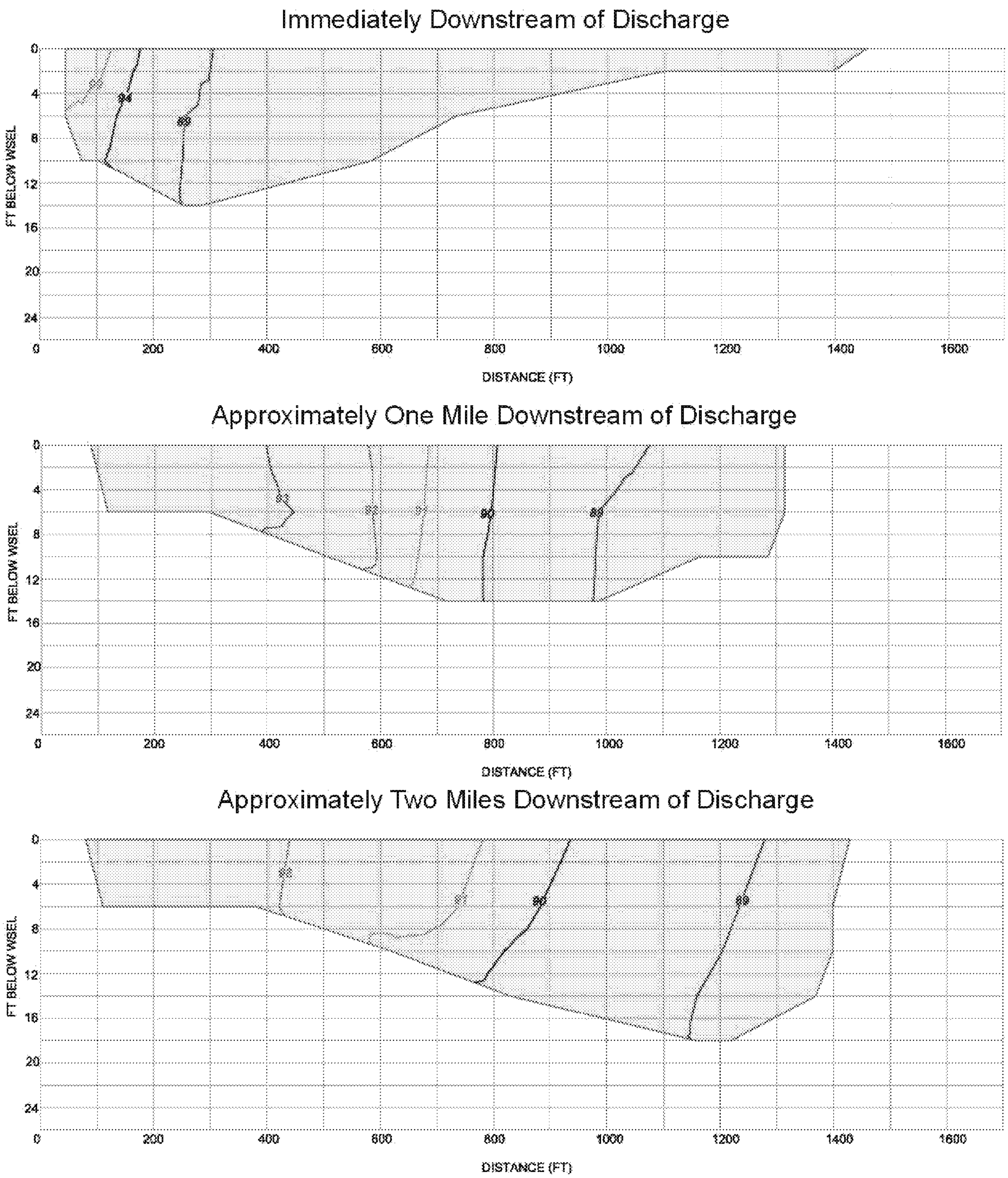


Figure 6-4 Distribution of elevated temperatures from LEC's thermal discharge in cross-section at three separate locations in the LMOR based on modeling of conditions from July 21, 2006.

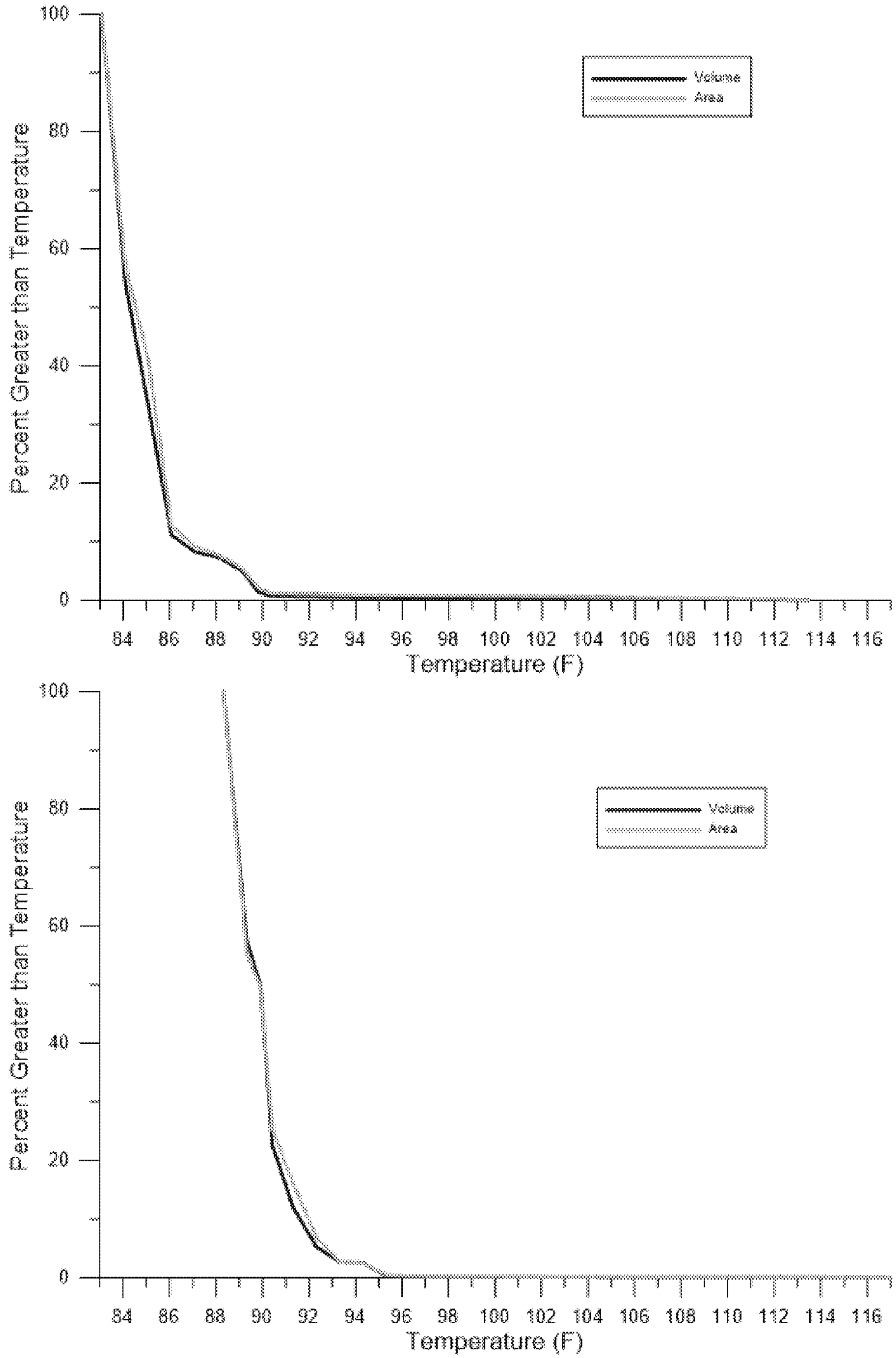


Figure 6-5 Percent of areas and volumes greater than specified temperatures based on modeling of LEC's thermal plume from June 22, 2006 (top panel) and July 21, 2006 (bottom panel).

June 2006 Model

Depth (ft).	Distance Across Model Grid																			
	533[1]	578	623	668	713	758	803	848	893	938	983	1028	1,073	1,118	1,163	1,208	1,253	1,298	1,343	1,388
0	7.3	7.3	9.3	5.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	166.8	12.8	11.5	16.5	40.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9		8.7	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0								
13				9.5	0.0	0.0	0.0	0.0												

July 2006 Model

Depth (ft).	Distance Across Model Grid																			
	533[1]	578	623	668	713	758	803	848	893	938	983	1,028	1,073	1,118	1,163	1,208	1,253	1,298	1,343	1,388
0	4.2	4.7	11.8	3.8	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	31.8	317.8	48.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8		7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0									
12					0.0															

Figure 6-6 Number of minutes each particle is exposed to temperatures exceeding MO WQS from LEC's thermal discharge based on modeled conditions on June 22, 2006 and July 21, 2006.

[1] Approximate location of south shore of the LMOR.

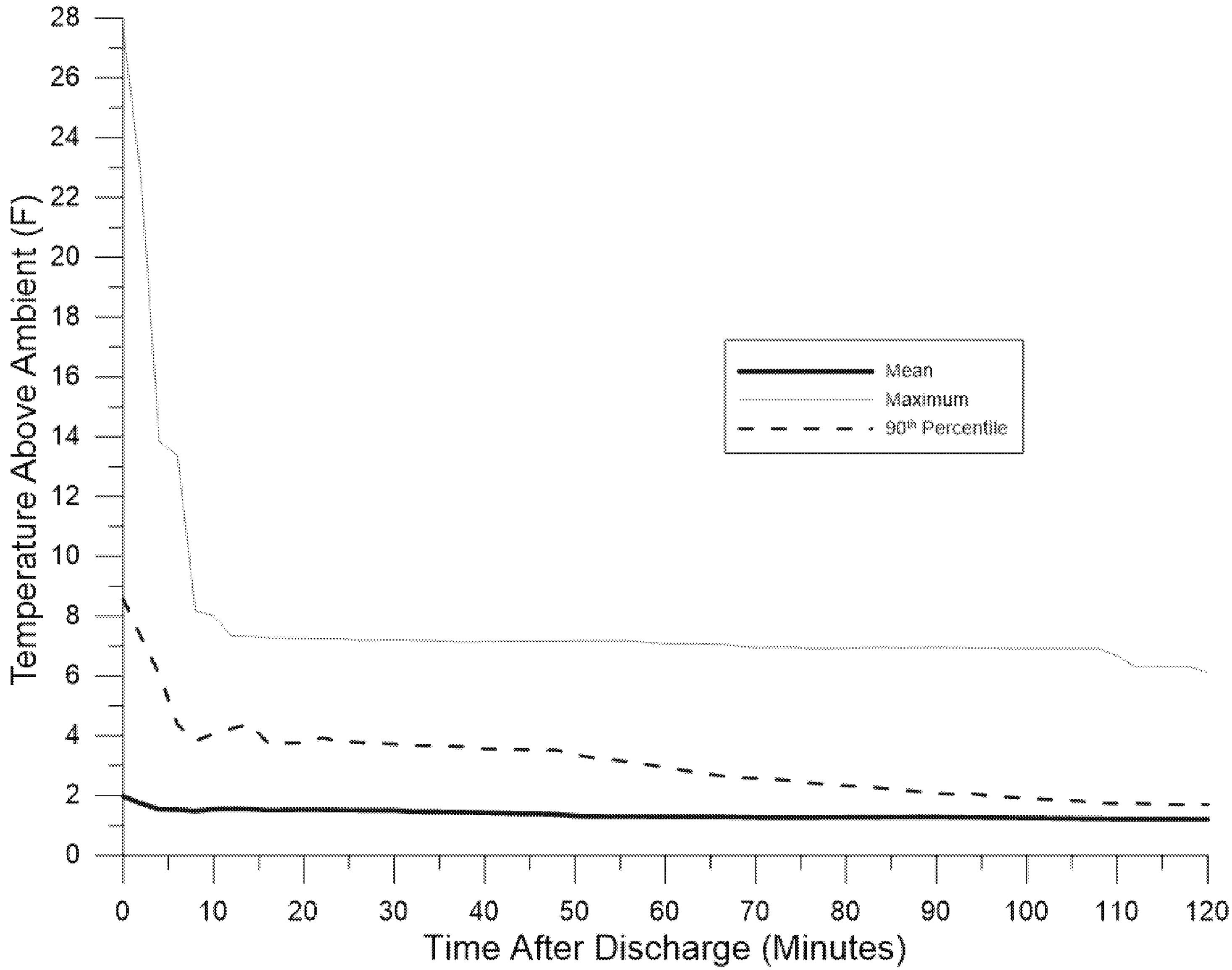


Figure 6-7 Probability distributions of temperature exposures by modeled particles released upstream of LEC's thermal discharge based on modeled conditions on July 21, 2006, the most extreme conditions.

6.1.4 Long Term Exposures to Elevated Temperatures

The previous two subsections described the short-term temperature exposures under observed extreme worst-case conditions. These extreme temperatures are appropriate for evaluating the potential for acute effects resulting from short-term exposures. However, they are not the best measure for evaluating the potential for sublethal effects, such as growth and reproduction, resulting from long-term exposures to elevated temperatures.

Evaluation of long-term temperature exposures for aquatic organisms was based on actual measured temperatures rather that worst-case exposures that occurred on a modeled single day, as used for evaluation of acute mortality. Analysis of actual measurements were made at a location just downstream of the LEC discharge canal, which was assumed to be at the downstream end of the Zone of Initial Dilution (ZID) of the discharge plume by ambient river waters. This analysis revealed that most of the time temperatures were 4°F or less above ambient. Further, only 10 percent of the measurements were greater than 6°F above ambient and all of these were during the coldest periods of the year with little biological productivity. Hence, an assumption of 6°F above ambient is a highly conservative assumption of potential long-term exposure of aquatic organisms to the LEC thermal discharge

6.2 SELECTION OF REPRESENTATIVE IMPORTANT SPECIES

The second step in the predictive assessment for the LEC was to select species to represent the BIC components not deemed to have low potential impact. The Guidance Manual (USEPA 1974 and 1977) recognizes that it is impractical to study and assess in great detail every species at a site, and it is therefore necessary to select a smaller group to be representative of the balanced indigenous community. These selected species are designated as RIS. Generally, five to 15 RIS are chosen to represent the community.

According to the Guidance Manual, criteria for selecting RIS include that the species are:

- Representative, in terms of their biological requirements, of a balanced indigenous community of fish, shellfish, or wildlife;
- Commercially or recreationally valuable;
- Threatened or endangered;
- Critical to the structure and function of the ecosystem (e.g., habitat formers such as submerged aquatic vegetation);
- Potentially capable of becoming localized nuisance species; and
- Necessary in the food chain for the well-being of species determined above.

Other considerations for RIS selection include the extent of the species' seasonal occurrence and abundance within the thermal plume, their thermal sensitivity, and the quantity and quality of information available for the assessment, such as data on thermal tolerance. While many or most fish species in the LMOR may be year-round residents within the area, some are more transient, using the area for adult spawning migrations, dispersal of young to habitats more suitable for the species, or refuge from natural environmental conditions (e.g., high flows or non-preferred water temperatures). For fish species, the results of catch data collected during the monthly surveys for the retrospective assessment provide an additional basis for RIS selection.

Benthic macroinvertebrates as a biotic category was not determined to have a low potential for impact (Section 4). However, they were not included as a RIS in this predictive assessment as they are best addressed in the retrospective assessment (Section 5) for the following reasons:

- The primary purpose of the predictive assessment is to predict under modeled hypothetical conditions the potential effect of an additional heat source on the components of the biotic community that are either mobile or otherwise transient in occurrence. Benthic macroinvertebrates generally are neither.
- There are no documented occurrences of endangered benthic macroinvertebrates or of species having commercial or recreational importance in the study area.
- The availability of results from rigorous lab testing of thermal tolerance for relevant species in the lower Missouri River is limited.
- Being sedentary in nature, benthic macroinvertebrates are recognized as ideal organisms for determining toxicity and pollutant effects, often as indicator species, and thus are ideal for a retrospective assessment of past and present influence of the thermal discharge on the community.

Using the above criteria, the following RIS were selected for this predictive assessment:

RIS	**Rationale**
Channel catfish	Recreational species
Emerald shiner	Important food chain species
Gizzard shad	Important food chain species
Pallid sturgeon	Endangered species
Walleye/sauger	Recreational and temperature sensitive species
White crappie	Recreational and temperature sensitive species

The expected seasonal occurrence of life stages for these species is shown in Figure 6-8 based on local field studies and available literature. A discussion of life history and distribution of each of these RIS in the LMOR is provided below. Thermal tolerance of each RIS is presented and addressed in Section 6.3.

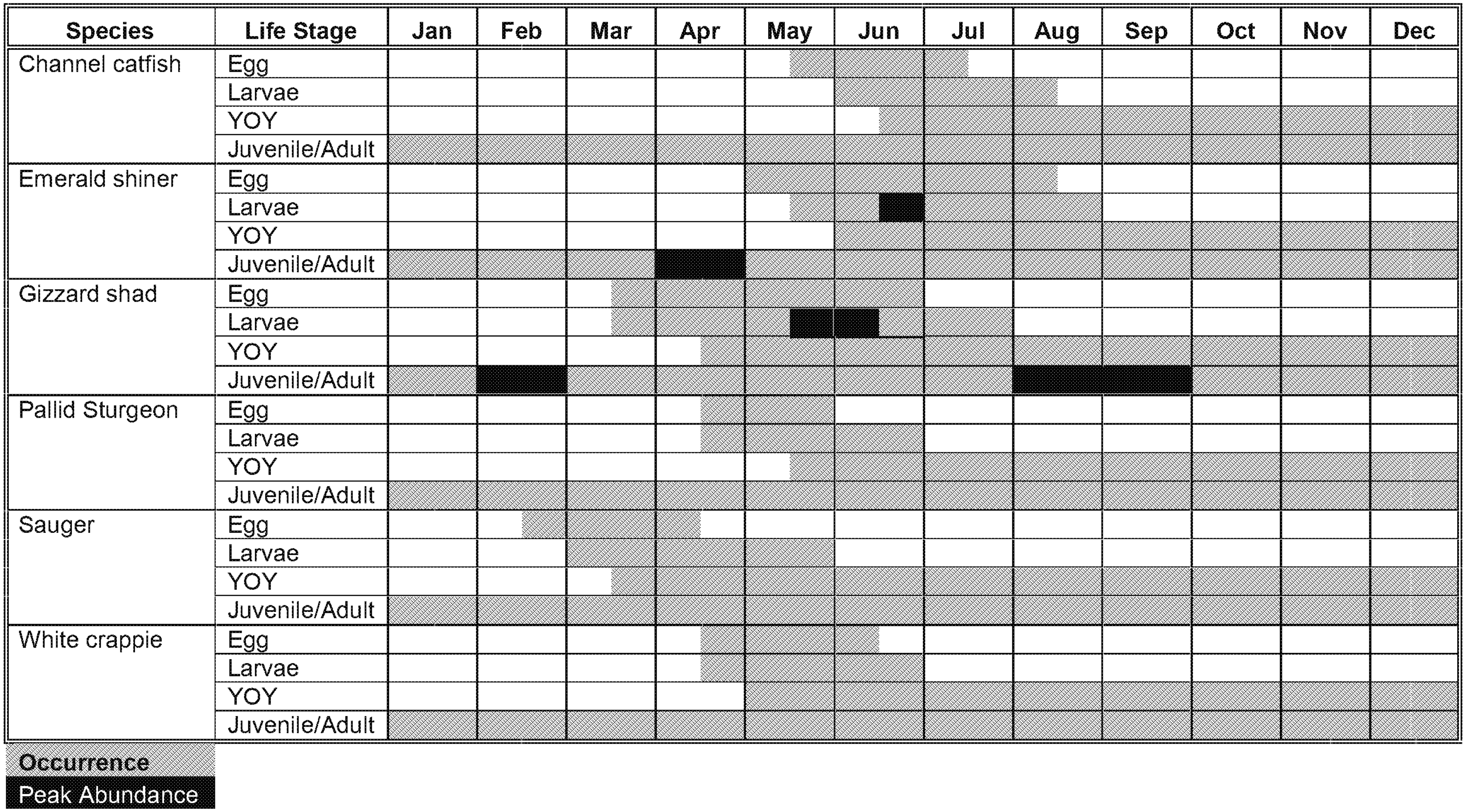


Figure 6-8 Expected seasonal occurrence of RIS life stages in vicinity of LEC based on actual collections and/or available scientific literature.

6.2.1 Channel Catfish

Channel catfish (*Ictalurus punctatus*) was selected as an RIS as it is one of the most popular target species of recreational fishermen in the LMOR (MDOC 2011). Channel catfish is a large, omnivorous riverine catfish species, with the state record catch in Missouri waters is 34.6 lb (Pfleiger 1997). Channel catfish once were a major component of the commercial fishery in the Missouri River, along with flathead catfish and blue catfish. However, the commercial fishery for these three species was closed in July 1992 in response to their declining abundance and population size structure, as well as to reallocate their exploitation to recreational anglers (Mestl 1999, Stanovick 1999, Travnichek and Clemons 2001).

Channel catfish typically spawn in late spring and early summer when water temperatures reach 65°F or more (McMahon and Terrell 1982, Pitlo et al. 2004). Spawning occurs over a range of temperatures from 69.8°F to 84.2°F, with an optimal temperature of 80.6°F (Hubert 1999). Based on water temperatures recorded in the vicinity of the LEC, sustained temperatures in this range (70–84°F) would correspond with the period from late May through June. Often there are two spawning peaks, as apparent from a bimodal size distribution of young catfish, possibly resulting from an interruption by unfavorable conditions such as river discharge or temperature (Pitlo et al. 2004).

Channel catfish eggs are deposited in nests in a gelatinous mass. Incubation lasts for 5.5 to 10 days at 75-82°F (Holland-Bartels and Duval 1988). The male tends the nest while eggs hatch and stays there for about one week after hatching to guard the fry. Fry are less vulnerable to predation in turbid water and aggregate at the edge of the channel over mud or sand bottoms (McMahon and Terrell 1982). Early growth is variable among year classes and apparently is dependent upon existing conditions (Pitlo et al. 2004).

Young channel catfish occupy the main channel or main channel border habitats during their first year (Pitlo et al. 2004). Adults may be found in many habitats including channels and large open areas, but prefer habitat with woody debris, bank cavities, and moderate currents (Koel et al. 1998). Newcomb (1989) found them to be concentrated in deep scour holes in eddy current areas around rock wing dikes at depths >12 ft and velocities <0.9 ft/sec in the Missouri River in Nebraska. In daylight they seek depths with cover and current, while at night or in rising water levels they feed in shallower depths. Most channel catfish do not stray far from their home pool, but some have been shown to make extensive movements (Pitlo et al. 2004). For example, Dames et al. (1989) found that LMOR channel catfish traveled considerably long distances in short time periods and demonstrated changing seasonal patterns in distance and direction. Downstream movements generally occurred during autumn season, while upstream movements and migration from the LMOR into tributaries was more frequent in the spring. Adult channel catfish overwinter in deep water, usually associated with structure such as boulders or debris, and exhibited little movement in the LMOR during the overwinter period (Garrett 2010).

6.2.2 Emerald Shiner

The emerald shiner (*Notropis atherinoides*) was selected as an RIS because of its importance as a prey species in the food chain of the LMOR and the availability of thermal tolerance data derived from controlled laboratory testing. It is one of the most abundant minnows in the Missouri and Mississippi rivers. For example, emerald shiner was the fourth-most abundant species caught in the vicinity of the LEC between 2017and 2018. This species is a common inhabitant of open channels of large river and streams with low to moderate gradient (Pflieger 1997) where it forms large schools in midwater or near-surface depths.

Breeding adults occur throughout the Missouri River from late May through early July during what appears to be a prolonged spawning period (Pflieger 1997). A prolonged spawning period would allow each fish to spawn more than once per season (Becker 1983). Non-adhesive eggs are broadcast at night in shallow water near the surface where they sink to the bottom over rocky substrate, hard sand, or firm mud. The eggs hatch in 24 to 36 hours and the yolk-sac larvae remain on the bottom for approximately four days before joining large schools near the surface (Becker 1983, Pflieger 1997). In the LMOR, the eggs and fry are not likely subject to drifting downriver and no eggs and only a small number of emerald shiner larvae in ichthyoplankton were collected in the vicinity of the LEC from 2015 to 2018.

Schramm (2004) generally characterized the habitat of juvenile and adult emerald shiners to be channel border and backwater areas, while Schloesser et al. (2011) described emerald shiner as a habitat generalist. Reeves (2006) commonly collected the juveniles and adults in wing-dike and wing-dike sandbar mesohabitats as did Ameren's 2017-2018 survey by electrofishing and seining.

6.2.3 Gizzard Shad

Gizzard shad (*Dorosoma cepediatum*) was selected as an RIS because of its importance as a prey species in the LMOR. Its productivity is linked to its role in the trophic structure of the community, since it feeds on primary producers (phytoplankton and periphyton) and planktonic consumers (zooplankton and some fish eggs and larvae). Gizzard shad occur in every stream basin in Missouri but is most abundant in the Mississippi and Missouri Rivers (Pflieger 1997). Much of the Missouri River population has been associated with the lower channelized river segments, where gizzard shad are able to thrive as prolonged swimmers (Galat et al. 2005b). It is so abundant in some locations that it is sometimes considered a nuisance species, possibly competing with other species for food and space. Gizzard shad are particularly susceptible to mortality resulting from sudden and extreme changes in temperature, with winter die-offs at temperatures below 38° F (Williamson and Nelson 1985).

Gizzard shad have been reported to spawn at temperatures ranging from 50°F to 82°F, depending on location (Heidinger and Brooks 2005), and spawning can be protracted over 3 to 4 months (Tisa and Ney 1991, Michaletz 1997). Based on water temperatures recorded in the vicinity of the LEC, sustained temperatures in this range would correspond with the period from approximately late March to late June. Spawning activity had been correlated with rapidly rising water levels and stimulated at water temperatures over 60 °F (Williamson and Nelson 1985). Aggregations of gizzard shad will migrate upstream to spawn in shallow water, less than 5 ft in relatively protected areas (Pflieger 1997, Williamson and Nelson 1985). Eggs are adhesive, attach to the bottom and hatch in 36 to 95 hours after fertilization in water temperatures ranging from 62 to 80 °F (Heidinger and Brooks 2005). No gizzard shad eggs were collected in ichthyoplankton sampling in the vicinity of the LEC from 2015 to 2018.

In the Missouri River, young gizzard shad are abundant along the shore in late May and June (Pflieger 1997). Young-of-year (YOY) gizzard shad began to appear in the LEC impingement collections during 2005–2006 at lengths of 22–32 millimeters (mm) total length (TL) from mid-May to mid-July. Young gizzard shad grow very quickly (e.g., 0.44–1.33 mm/day as larvae and 0.30–1.0 mm/day as juveniles), reaching 6 to 7 in. by the end of their first year (Tisa and Ney 1991, Michaletz 1997, Heidinger and Brooks 2005). This rapid growth rate limits the period when they are effectively preyed upon to approximately their first 6 months of life. By September they become too large for all but the largest predators and may reach a maximum size of 175 mm TL (6.9 in.) by December.

6.2.4 Pallid Sturgeon

Pallid sturgeon (*Scaphirhynchus albus*) was selected as an RIS based upon its status as a federally listed and state-listed endangered species. Pallid sturgeon was first recognized as a species distinct from the shovelnose sturgeon in 1905 and was listed as endangered on

September 6, 1990 (USFWS 2007). The pallid sturgeon is adapted to live near the bottom of large, free-flowing rivers in turbid waters. It prefers a diversity of water depths and velocities such as typically found in braided channels and around islands and sand bars and flats (USFWS 2007, 2014). It is considered endemic to the Missouri River, as well as the Mississippi River and the lower reaches of the Yellowstone, Platte, and Kansas rivers (Dryer and Sandoval 1993; USFWS 2014).

The pallid sturgeon's current range is fragmented by mainstem dams on the Missouri River and its presence is considered scarce throughout much of its former range (USFWS 2007). Catch rates of pallid sturgeon have been consistently low recently in the most downstream reaches of the LMOR near the LEC (Herman et al. 2014; Herman and Wrasse 2015, 2016), and there is no evidence for increasing relative abundance in the LMOR despite stocking efforts (Wildhaber et al. 2014).

Recent observations have provided evidence of limited recruitment in the LMOR and Mississippi River. Three confirmed larval pallid sturgeon were collected in 2000 from a side channel (Lisbon Chute) at RM 217 (USNRC 2014), approximately 160 miles upstream of the LEC. Two naturally reproduced larval pallid sturgeon were captured in 2014 by the MDC near St. Louis and their identification was confirmed by DNA analysis (Crosby 2015). More recently, additional collections of a small number of wild-spawned pallid sturgeon larvae and suspected wild juvenile pallid sturgeon from the lower Missouri River have been confirmed (Jacobson et al. 2016). Regardless of these observations, the population is considered neither stable nor self-sustaining (Steffenson 2012, USFWS 2014) and it primarily consists of older individuals.

In the lower Missouri River, juvenile and adult pallid sturgeon primarily have been observed in channel border habitats associated with engineered structures but also has been documented inside channels with flowing water (USFWS 2014). In the Middle Mississippi River (MMR) where the river habitat is similar to that of the LMOR, sonic-tagged pallid sturgeon (614-888 mm standard length) occupied the main channel most frequently (39 percent), likely due to the predominance of this habitat type, followed by main-channel border (26 percent) and between wing dikes (14 percent) (Hurley et al. 2004). This pattern was similar across all seasons, regardless of water temperature, except during high spring flows at temperatures between 50°F and 68°F, when they increasingly used areas between wing dikes. Koch et al. (2012) conducted a similar study with sonic-tagged adult pallid sturgeon (>600 mm fork length [FL]) on the MMR that refined data on the selection of specific habitats from which they concluded that wing dike flows and substrates may provide otherwise missing habitat complexity, e.g., scour holes of depths 6-12 meters and sand substrate.

Information on pallid sturgeon reproduction is scarce, although currently there are efforts aimed at improving the understanding of pallid sturgeon reproductive biology and spawning behavior. Pre-spawning pallid sturgeon generally move upstream beginning in the late fall and early spring (DeLonay et al. 2012). Spawning in the LMOR appears to be associated with increasing day length, increasing water temperature, and typically higher river flows and generally occurs from the end of April through May. Over their whole range, spawning has been observed from March to July with fish in the northern part of the range spawning later than those in the southern part (USFWS 2014). While increasingly more information is becoming available on pallid sturgeon spawning habitat preferences, the relative spawning success remains unknown. DeLonay et al. (2012) demonstrated that during the upstream spawning migration, pallid sturgeon preferred the slower currents of the inside channel bends. McElroy et al. (2012), interpreting Delonay et al. (2010) data, hypothesized that the use of slower currents in the inside channel bends of the Missouri River, frequently traversing the river thalweg from inside bend to inside bend, for upstream migration afforded adult pallid sturgeon optimization of their migration through reduced energetic cost and shorter pathways. Wildhaber et al. (2007) assumed that, like other sturgeon species, spawning occurs over coarse substrate in river currents in or adjacent to the main channel.

Sturgeon eggs are adhesive. Newly hatched larvae are attracted to light and migrate upward into the water column towards the surface to enter the current. Kynard et al. (2002) observed pallid sturgeon larvae swimming off the bottom at day-2, swimming increasingly higher off the substrate and into current at day 4, and actively swimming in circles at the surface on days 7-8. They remain pelagic and may drift downstream for up to 13 days and several hundred kilometers (km) depending on river flow, water temperature, and growth rates (Braaten et al. 2012, USFWS 2014). Unlike other sturgeon species, pallid sturgeon larvae appear to drift during both day and night (Braaten et al. 2012). Braaten et al. (2010) showed that freely drifting pallid sturgeon larvae were most closely associated with the bottom 0.5 meters of the water column. Drifting larvae swimming height within the water column was related to development stage, habitat preference, migratory style and migratory distance (Kynard et al. 2002). In addition, drifting larval distribution was greatest in mid-channel and outside bend habitat locations where currents were highest. Larval sturgeon transition from free drifting to settling into benthic habitats when the larvae reach approximately 18 to 20 mm in length (Braaten et al. 2010).

Little is known regarding habitat preferences for settled larval and young pallid sturgeon, however they are surmised to be similar to those for the closely related shovelnose sturgeon larval and young habitat preferences (USFWS 2014). Based on this premise, larval pallid sturgeon (20-30 mm) would prefer side-channel, low velocity (1.6-2.2 fps) habitats for settling shortly after their drifting period. By the time they would reach 30-40 mm length, Age-0 sturgeon would show a preference for habitats with faster velocity flows (Ridenour et al. 2011).

All species of sturgeon are highly migratory and capable of long-range (> 300 km) movements, often moving freely among multiple large river systems (Tripp et al. 2019). While these movements are known to be triggered by river stage and temperature, they are highly variable among populations (Tripp et al. 2019). For example, shovelnose sturgeon in the northern regions (e.g. RM 595-734) of the Missouri River exhibit only short-range movement patterns while sturgeon in the LMOR (RM 130-150) have migration patterns that include both short and long distances (Wildhaber et al. 2011). Wildhaber et al. (2011) speculates that these differences among populations within the Missouri River maybe a result of nearby tributary use for spawning by northern populations or altered environmental cues from upstream reservoirs with regulated flows. Tripp et al. (2019) found that pallid and other sturgeon species within the Missouri River exhibited seasonal movements out of and back to core areas at different times of the year, with greater movement for pallid sturgeon observed in the summer and fall. Pallid sturgeon seasonal movements within the Missouri River were closely tied to temperature along with movements increasing with rising river water and decreasing with low water levels (Tripp et al. 2019).

6.2.5 Walleye/sauger

Both walleye (*Sander vitreus*) and the closely related sauger (Sander canadensis), were selected as RIS due to its temperature sensitivity and importance as recreational species in parts of the Missouri River. In this study, they are combined together since their temperature sensitivities are similar and the egg and larval stages are exceedingly difficult to distinguish using normal identification methods. Native to freshwater rivers and lakes primarily east of the Rocky Mountains and west of the Appalachians (McMahon et al. 1984), walleye is one of the most widespread fishes in interior North America (Hoagstrom and Berry 2010). Walleye is known to be a migratory species, navigating extensive distances for spawning, suitable foraging or staging areas and returning (homing behavior) to specific area (Haxton et al. 2015). Within large, fragmented rivers such as the Missouri River, walleye movement can be restricted by dams and other barriers that may not be designed to facilitate fish movement. However, Haxton et al. (2015)

found that walleye movement was limited even within contiguous, unimpounded reaches of a large fragmented river, suggesting that dams might not be the barrier to some populations. The limited walleye movement among river reaches, even by only a few individuals, could be necessary to maintain the genetic diversity within a fragmented river population (Haxton et al. 2015).

Spawning of adults typically occurs at night from mid-February through early April in temperatures from 38 to 58°F within flowing water and clean rocky substrate (Auer 1982). Spawning habitats of shallow shoreline areas, shoals, riffles, and the rock substrate at the base of dams are preferred (McMahon et al. 1984). Demersal, adhesive eggs are broadcasted and fertilized during release onto unguarded coarse gravel, boulder, and rock substrate to which the eggs adhere (Auer 1982; Cross and Collins 1995). The 1.5 to 2.1 mm diameter eggs hatch in approximately 14 to 21 days at water temperatures ranging from 46.4 to 59°F and require well-oxygenated water for high survival and growth (Auer 1982; McMahon et al. 1984).

Newly hatched fry will absorb yolk-sac within 3 to 5 days during which point they are transported by water flows to lakes or impounded river areas. Fry begin feeding at 15 to 25 mm in length and remain photopositive until reaching lengths of 25 to 40 mm after which the demersal fry, juveniles and adults seek shelter to avoid periods of intense light (McMahon et al. 1984).

Adult walleyes are often found under cover of boulders, log piles, brush, and submerged vegetation during the day and feed at night after moving inshore (McMahon et al. 1984). They prefer areas of slight currents throughout the year, with the exception of winter periods when they avoid turbulent areas. Optimal growth temperatures and dissolved oxygen range from 68 to 75°F and 3-5 mg/l, respectively (McMahon et al. 1984).

Often confused with the walleye, the sauger (*Sander canadensis*) is less abundant within the Missouri River. The sauger typically is shorter, has a more slender body than walleye, and is identifiable by the larger dark brown saddle blotches, along with spots on its dorsal fin (Tomelleri and Eberle 1990). A white tip on its tail and dark membranes on the posterior end of the dorsal fin can often distinguish the walleye (Tomelleri and Eberle 1990). Sauger has been found to prefer deeper water and are more tolerant of turbid, silted bottomed waters than walleye (Trautman 1981).

6.2.6 White Crappie

White crappie (*Pomoxis annularis*) was selected as an RIS due to its temperature sensitivity and its importance as a recreational sportfish in the LMOR. It is native to freshwater lakes, streams, and rivers from the southern Great Lakes to Texas and Alabama, west to Nebraska, east to North Carolina, then west of Appalachian Mountains to New York (Edwards et al. 1982). Within river systems white crappie are most commonly found in low velocity areas within pools and backwater areas away from the main channel in clearer waters (Edwards et al. 1982). Within Missouri rivers, white crappie prefer locations away from the main channel in sluggish pools or backwater areas of low to zero velocity (Pflieger 1975). Within the Missouri River, fish surveys identified higher abundance of white crappie in mid and upper river segments than those segments within the LMOR (Berry et al. 2004).

Mature males construct and guard nests over at depths of 4 inches to 14 feet near vegetation or other cover (Edwards et al. 1982). Siefert (1968) also found spawning adults selected nesting locations near objects and bottom vegetation but had no strong substrate preference. Spawning occurs from March to July after water temperatures reach 55-57°F peaking at 61-68°F, however spawning has been observed in Missouri at water temperatures as high as 78.8°F (Edwards et al. 1982). Demersal, colorless, adhesive eggs with a diameter of 0.8 to 0.9 mm typically hatch in 27 to 93 hours depending on water temperature (Auer 1982). Newly hatched fry range in length from 1.2 to 2.6 mm, depart the nest at slightly larger lengths (4.1 to 4.6 mm), and fully absorb the yolk-sac before reaching 5 mm (Auer 1982, Siefert 1968, 1969).

Adult white crappie populations can be highly dependent on cover availability. Adults are found to congregate around submerged trees, stumps, brush, aquatic vegetation, and boulders (Edwards et al. 1982). Other limitations on population abundance include hydraulic conditions, predation, and the availability of type and size of food especially at critical stages in the life cycle (McDonough and Buchanon 1991). In the Wabash River in Indiana, adult white crappie showed preference to temperatures of 80 to 80.6°F near a thermal effluent but were not found in heated discharge above 87.8°F (Edwards et al. 1982).

6.3 ASSESSMENT OF POTENTIAL BIOTHERMAL EFFECTS

The response of the RIS to the LEC's thermal plume was evaluated using thermal response data obtained in laboratory studies (Appendix C Table C-1). This laboratory data was supplemented by data collected during field studies (EPRI 2013) on maximum temperatures at which the RIS were found to occur and potentially survive, at least over a short term (Appendix C Table C-2). Most of the available data evaluated response to rapid changes in temperature, as would commonly be experienced with exposure to a thermal plume and conventionally defined as the incipient lethal temperature method (Brungs and Jones 1977). Use of these laboratory data tends to be conservatively protective since organisms can acclimate and adapt, both physiologically and genetically, to changed temperature regimes, recover from short-term thermal stress and utilize lower temperature areas of the waterbody as refuge from stressful temperatures when necessary (Bevelheimer and Coutant 2004, Reash 2008, Bevelheimer 2008).

Using these laboratory data, this predictive assessment focuses on addressing the following four questions with regard to the magnitude, areal extent and frequency of occurrence of elevated temperature exposures from the LEC's thermal discharge and the effects that such exposures could have on the fish community components in the LMOR:

- Are the areal extent and probability of occurrence of mortality resulting from thermal exposures sufficiently large to adversely affect the populations of planktonic individuals, including the egg and larval stages of fish, as they drift past the LEC facility?
- Are rapid temperature declines during winter if the LEC abruptly ceases discharging heat sufficient to adversely affect the populations of fish in the LMOR from mortality associated with cold shock?
- Are the effects of long-term exposures to elevated temperatures from the LEC's thermal discharge of sufficient intensity, magnitude and frequency of occurrence so as to adversely affect the reproduction and development of fish in the LMOR?
- Are the cross-sectional areas from which motile individuals are excluded as a result of thermal avoidance sufficiently large and likely to occur frequently enough so as to block migratory pathways for fish in the LMOR?

These questions were addressed in this predictive assessment by comparing seasonal occurrence of the RIS in the LMOR in the vicinity of the discharge and biothermal response information for these species obtained in laboratory studies to the predicted seasonal ambient and plume temperatures to which the organisms may be exposed. As previously noted, temperature exposures were estimated from plume modeling of extreme conditions in late spring and summer.

For each question, the potential for the LEC's thermal discharge to have an appreciable impact on the populations of the RIS was assessed by evaluating the thermal effects predictions in the context of:

- Species life-cycle requirements and characteristics;
- Species ranges and distributions;
- The relative amount of available habitat in the LMOR; and
- Potential for reversal of effects.

6.3.1 Potential Effects from Increased Mortality

Aquatic organisms can adjust to the thermal environment physiologically, thereby shifting their tolerance range, but this acclimation has limits and ultimately a water temperature may be reached that would be lethal (Figure 6-9). The upper and lower lethal limits of thermal tolerance are typically determined by laboratory experiments and are defined as the temperature resulting in death of 5, 50, or 95 percent of the test organisms (TL5, TL50, TL95). Immobilization or death resulting from sudden increases or decreases in water temperature beyond an organism's upper or lower incipient tolerance limit (LILT) is often referred to as "heat shock" or "cold shock," respectively.

The tolerance of organisms to extremes of temperature change is influenced by three factors: 1) their genetic ability to adapt to thermal changes within their characteristic temperature range; 2) the acclimation temperature prior to exposure to a change; and 3) the duration of exposure to the elevated or lowered temperature (Coutant 1972). The first factor, genetic ability to adapt to

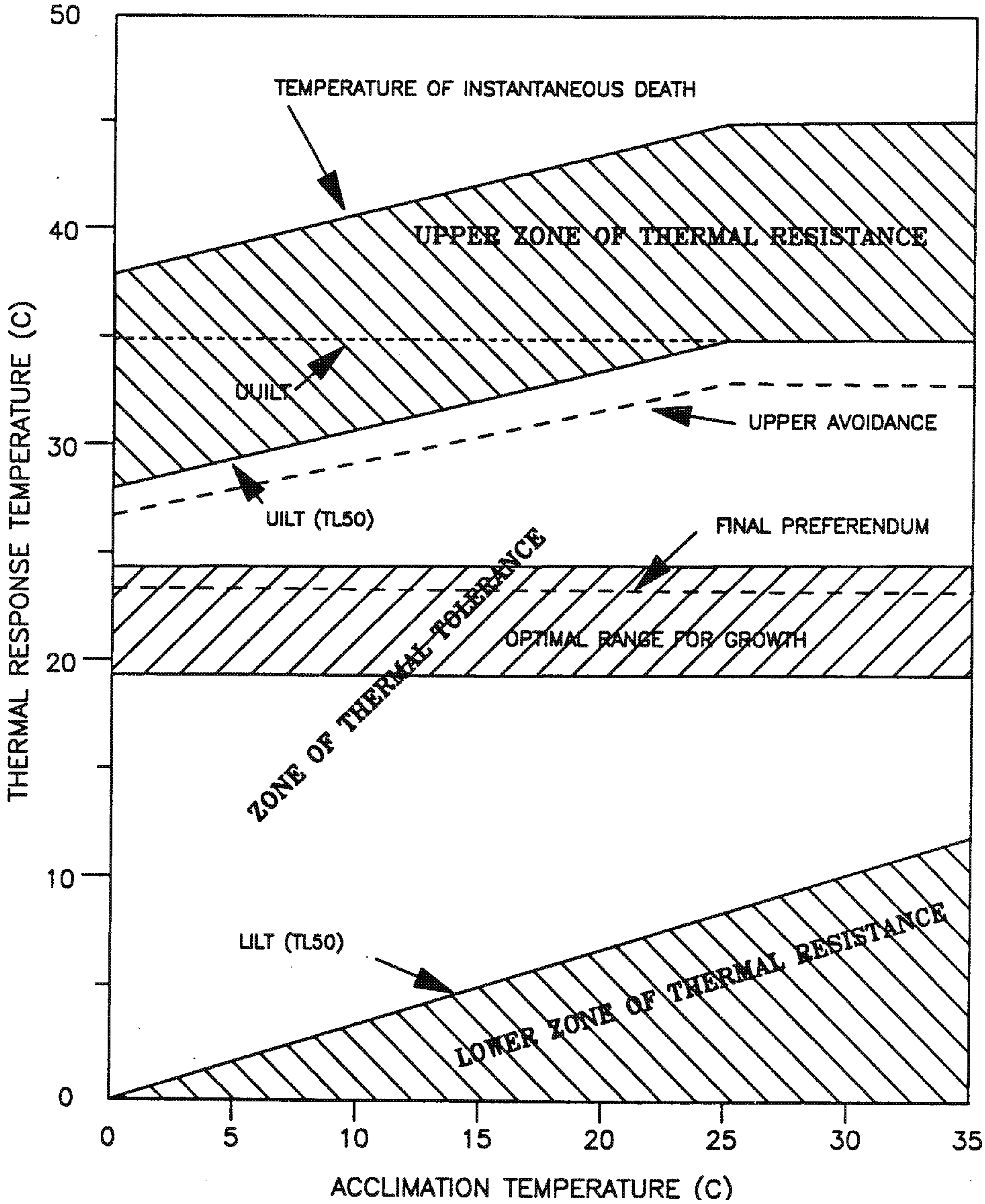


Figure 6-9 Interrelationship of various thermal effect parameters and acclimation temperature.

temperature changes, differs among species and among developmental stages within a particular species (Hochachka and Somero 1971). For example, striped bass tolerate higher temperatures than salmon, and juvenile striped bass have higher tolerances than adult striped bass (EA 1978a, Coutant 1970).

The second factor, the temperature to which an organism has become physiologically adapted (acclimation temperature), affects aquatic organisms' upper and lower temperature tolerance to long- and short-term periods of exposure (Brett 1956; Coutant 1972; Lauer et al. 1974; Figure 6-9). True acclimation to changed temperature requires several days to more than a week (Brett 1941; Fry 1971; Hochachka and Somero 1971). For long-term exposure, the upper incipient lethal temperature (UILT), which is the highest temperature at which 50 percent (TL50) of a sample of organisms can survive long-term exposure (24 hours to one week), is determined for each organism at the highest sustainable acclimation temperature. The lowest temperature at which 50 percent (TL50) of the warm acclimated organisms can survive long-term exposure is the LILT.

Tolerance to short-term (seconds to hours) exposures to temperature changes also depends on the organism's acclimation temperature (Lauer et al. 1974; EA 1978 a,b; IA 1978a,b,c,d; IA 1979; Greges and Schubel 1979). A sample of organisms acclimated to temperatures at the low end of their range of tolerance typically can tolerate larger increases in temperature than a sample of the same organisms acclimated to temperatures near the high end of their range of tolerance (Lauer et al. 1974). For example, striped bass post yolk-sac larvae acclimated to 68°F tolerated a 23.4°F temperature rise (equal to an exposure temperature of 91.4°F) for 5 minutes, whereas the same species life stage acclimated to 78.8°F tolerated only a 19.1°F rise (equal to an exposure temperature of 97.9°F) for the same exposure time (EA 1978a). Nonetheless, organisms acclimated to warmer temperatures generally can tolerate higher maximum temperatures than if they were acclimated to lower temperatures, as illustrated by temperatures reported by EPRI (2013).

The third factor crucial to tolerance of temperature change is duration of exposure (Coutant 1972). The tolerance of an organism to temperature changes is a direct function of exposure time. Organisms tolerate exposure to greater changes in temperature if the exposure is for a short period (Brett 1952). For example, striped bass acclimated to approximately 77°F survive an increase in temperature of 29°F (equal to an exposure temperature of 106°F) for 10 seconds, but tolerate an increase in temperature of only 18°F (equal to an exposure temperature of 95°F) for 60 minutes (EA 1979). This time-temperature aspect of tolerance of temperature change is crucial to an accurate and scientifically valid assessment of the potential for organisms to tolerate heat shock from potential exposure to the LEC's thermal plume.

6.3.1.1 Heat Shock

Thermal discharges, like that from the LEC, could theoretically cause mortality through exposures of aquatic organisms to temperatures exceeding their thermal tolerance resulting in heat shock. However, in the LMOR, the potential for heat shock from exposure to the LEC's thermal plume is limited to those life stages of the RIS that lack sufficient swimming ability to avoid lethal temperatures. This would include the very early life stages, such as eggs and larvae, that could drift into the thermal plume from river currents. The extensive literature on the effects of thermal plumes on fish demonstrate larger more motile life stages (juveniles and adults) will actively avoid temperatures outside their preferred ranges (Environment Canada 2014) and, hence, have virtually no potential of being subject to heat shock.

Data relevant to short-term temperature exposures for the early life stages of fish was available for only two of the RIS used in this assessment, emerald shiner and pallid sturgeon. These two species have relatively low thermal tolerances compared to other species found in the LMOR. Thus, the results based on these species can be used as conservative indicators of potential thermal effects on the other RIS species. These data were then compared to the thermal exposures based on particle tracking in the Flow-3D model described in Section 6.1.3 and illustrated in Figure 6-7 to assess the potential that the early life stages of these two species could potentially experience lethal temperatures. This particle tracking model documented that any exposures to elevated temperatures resulting from drifting into the LEC's thermal plume would be relatively short-term (e.g., ≤80 minutes). The potential for heat shock mortality to the other RIS was addressed qualitatively by comparing temperature exposures to information from long-term exposures such as UILT and Critical Thermal Maxima (CTM) (Beitinger et al. 2000). Available literature demonstrates that the heat tolerance from short-term exposures, such as through drift, will be much higher than either UILTs or CTMs. Hence, any evaluation using long-term thermal tolerance data can be considered very conservative. The results of these comparisons are presented for each of the RIS below.

Channel catfish

In the vicinity of the LEC, channel catfish spawn from late May through June. Eggs are deposited in nests in a gelatinous mass. Incubation typically lasts for 5.5 to 10 days. The male tends the nest while eggs hatch and stays there for about 1 week after hatching to guard the fry. Fry aggregate at the edge of the channel over mud or sand bottoms and have only limited vulnerability to the currents. This low vulnerability to drifting is reflected in the fact that no channel catfish eggs or larvae were collected during ichthyoplankton sampling in the vicinity of the LEC.

Channel catfish have wide geographic range including areas well south of the LEC it is reasonable to expect that they are tolerant of temperatures much higher than that observed in the LMOR. UILT values reported for larvae of this species acclimated to temperatures similar to that occurring in the LMOR was 95.90°F (Table 6-1). These temperatures encompassed less than 0.5 percent of the LMOR volume in the vicinity of the LEC (Figure 6-5). Drifting larvae would encounter these temperatures less that 10 percent of the time during the worst-case spring larval nursery period and none would be exposed to these temperatures for more than 16 minutes (Figure 6-6). Hence, there appears little likelihood that channel catfish larvae would experience exposures to lethal temperatures during drift.

Table 6-1 Thermal mortality temperatures used in this assessment of potential effects of the LEC's thermal plume to RIS in the LMOR.

Species	Life Stage	Thermal Effect Description	Acclimated Temperature (F)	Effect Temperature (F)	Reference Number[1]
Channel catfish	Larvae	Upper Incipient Lethal Temperature	84.20	95.90	191
Gizzard shad	YOY		86.00	96.80	172
Sauger	Juvenile	Upper Incipient Lethal Temperature	50.18	79.88	175
			53.60	80.06	175
			57.02	83.12	175
			60.80	83.48	175
			64.94	83.66	175
			67.82	85.10	175
			71.60	85.82	175
White crappie	Juvenile	Upper Incipient Lethal Temperature	80.60	91.40	184
			89.60	91.40	184

[1]**Reference citations in Appendix Table C-1.**

Emerald shiner

Emerald shiners have a prolonged spawning period in the LMOR extending from late May through early July. The prolonged spawning period would allow each fish to spawn more than once per season. Non-adhesive eggs are broadcast at night in shallow water near the surface where they sink to the bottom over rocky substrate, hard sand, or firm mud. The eggs hatch in 24 to 36 hours and the yolk-sac larvae remain on the bottom for approximately 4 days. Hence, both eggs and yolk-sac larvae should experience minimal exposure to the LEC's thermal plume. Thereafter, the developing larvae and juveniles swim up to join large schools near the surface and are subject to drifting downriver from river currents. In the two years of ichthyoplankton sampling in the vicinity of the LEC, no eggs and only 212 larvae of any minnow species were collected and only 15 of the larvae were identified as emerald shiner. These results support the assumption that most of the early life stages of this species occur in areas where they would not be exposed to the LEC's thermal plume.

While there are no short-term thermal tolerance data available for emerald shiner, there are for juveniles of a related species, spottail shiner (*Notropis hudsonius*). These data indicate that there might be very short-term exceedances of safe temperatures for juveniles of this species (Figure 6-10)[4]. However, these exceedances are of short duration (<10 min.) and occupy 1 percent or less of the surface area and volume in the vicinity of the LEC (Figure 6-5). Further, these measures of safe temperatures were developed using acclimation temperatures (79°F) less than that observed on the two dates modeled, representing extreme case (<1 percent) conditions of low river flow and high ambient temperature. Given the influence of acclimation temperatures on thermal tolerance, it is likely that the actual safe temperature might be higher than shown as illustrated in Figure 6-10.

Pallid sturgeon

While information on pallid sturgeon reproduction is scarce, spawning in the LMOR appears to generally occur from the end of April through May and likely over coarse substrate in river currents in or adjacent to the main channel. Sturgeon eggs are adhesive and should not be part of the drift and, hence, should experience minimal potential for exposure to the LEC's thermal plume. Newly hatched larvae migrate upward into the water column and enter the current. They remain pelagic and may drift downstream for up to 13 days and several hundred km depending on river flow, water temperature, and growth rates. However, when drifting they were most closely associated with the bottom 0.5 meters of the water column and larval abundance was greatest in mid-channel and outside-bend habitat locations where currents were highest. Larval sturgeon transition from free drifting to settling into benthic habitats when the larvae reach approximately 18 to 20 mm in length when they are approximately 30 days old and no longer part of the drift. In the two years of ichthyoplankton sampling in the vicinity of the LEC, no eggs and only one larvae of any sturgeon species were collected. This larva could have been either the more common shovelnose sturgeon or the rare pallid sturgeon but most likely the former owing to the relative abundance of each species.

The only short-term temperature tolerance data for pallid sturgeon were developed using an acclimation temperature of 72°F, more than 10°F less than observed in late spring of 2006. These data indicate that there might be very short-term exceedances of both safe temperatures and UILT for larvae of this species a (Figure 6-11)[3]. However, these exceedances are of short duration (<5 min. for UILT and <50 min. for safe temperatures) and occupy a small portion (<10 percent for safe temperatures and <1 percent for UILT) of the surface area and volume in the vicinity of LEC (Figure 6-5).

[4] See Appendix C Table C-1 for reference citations.

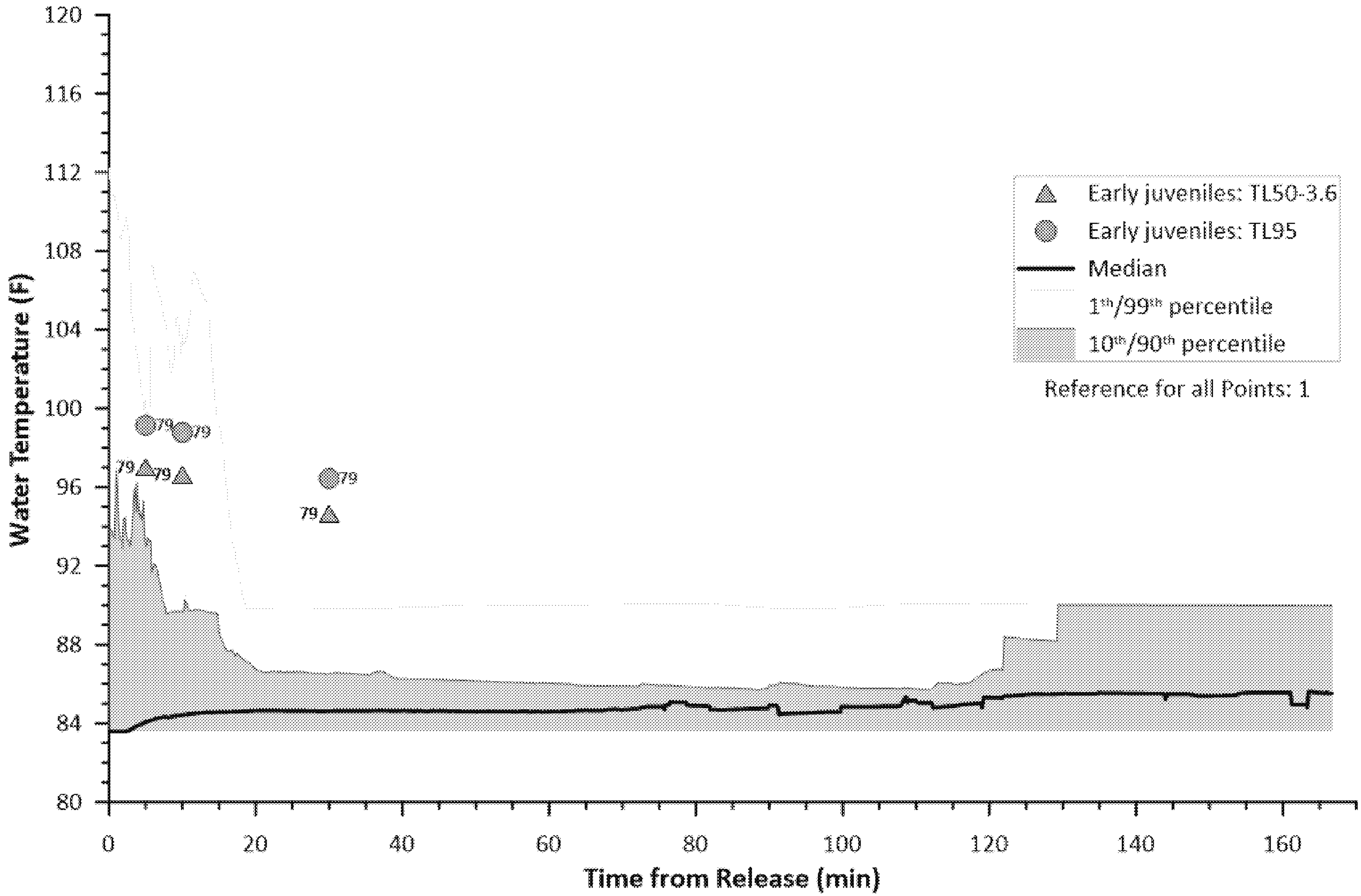


Figure 6-10 Short-term thermal tolerance of spottail shiner juveniles relative to temperature exposures based on particle tracking in the June 2006 model run. (Delta-T tolerance data are safe temperatures (TL50-3.6F). (Data labels indicate test acclimation temperature).

Further, these biothermal measures for pallid sturgeon larvae were developed using acclimation temperatures substantially less than that observed on the June date modeled, representing extreme case (<1 percent) conditions of low river flow and high ambient temperature. Given the influence of acclimation temperatures on thermal tolerance, it is likely that the actual safe temperature might be higher than listed in this figure. Finally, most of these exceedances occur near the discharge and up in the water column whereas pallid sturgeon larvae are most commonly found closer to the bottom

Gizzard shad

Gizzard shad appear to spawn in the vicinity of the LEC from approximately late March to late June. Spawning occurs in shallow water in relatively protected areas. The eggs are adhesive and attach to the bottom. These two characteristics indicate that eggs should not be carried by currents and accounts for the fact that no gizzard shad eggs were collected in the two years of ichthyoplankton sampling in the vicinity of the LEC. Larval gizzard shad are more commonly found up in the water column and this species accounted for just under 1 percent of the larvae collected in the 2-year sampling effort.

Unfortunately, there are no thermal tolerance data for gizzard shad larvae. However, the UILT for young of year (i.e., post larval) gizzard shad acclimated to temperatures comparable to those observed in the LMOR was 96.8°F (Table 6-1). Temperatures at or above 96.8°F encompassed less than 0.5 percent of the LMOR volume in the vicinity of the LEC (Figure 6-5). Drifting larvae would encounter these temperatures less that 10 percent of the time during the worst-case spring larval nursery period and none were exposed to these temperatures for more than 16 minutes (Figure 6-6). Hence, there appears little likelihood that gizzard shad larvae would experience exposures to lethal temperatures during drift.

Walleye/sauger

Spawning of the two closely related species, walleye and sauger, typically occurs during February and March in shallow shoreline areas, shoals, riffles, and the rock substrate at the base of dams. The demersal, adhesive eggs are broadcasted and fertilized during release onto unguarded coarse gravel, boulder, and rock substrate where the eggs adhere. Given their adhesive nature, eggs should not normally be part of the drift and none were collected in the two-year sampling effort in the vicinity of the LEC. Eggs hatch in approximately 14 to 21 days and the newly hatched fry absorb yolk-sac within 3 to 5 days. At that point, they are transported by water flows to lakes or impounded river areas. Fry begin feeding at 15 to 25 mm in length and remain photopositive until reaching lengths of 25 to 40 mm in a couple of months after which they become demersal and are no longer carried by the currents. Only a total of 20 larvae of these two species were collected in the two-year sampling effort in the vicinity of the LEC indicating that areas near the facility are not critical spawning and nursery habitat for this species. It is likely that the few larvae collected were transported into the area from upstream cool water spawning habitats by high spring flows.

Walleye and sauger are most commonly found in the vicinity of the LEC during April and early May when water temperatures typically range from 50 to 70°F. At these acclimation temperatures, the UILT for sauger ranges from just under 80°F to more than 85°F (Table 6-1). These temperatures would rarely, if ever, be encountered in the vicinity of the LEC's thermal discharge at times of the year when walleye and sauger would likely be present. Hence, there appears little likelihood that walleye or sauger larvae would experience exposures to lethal temperatures during drift.

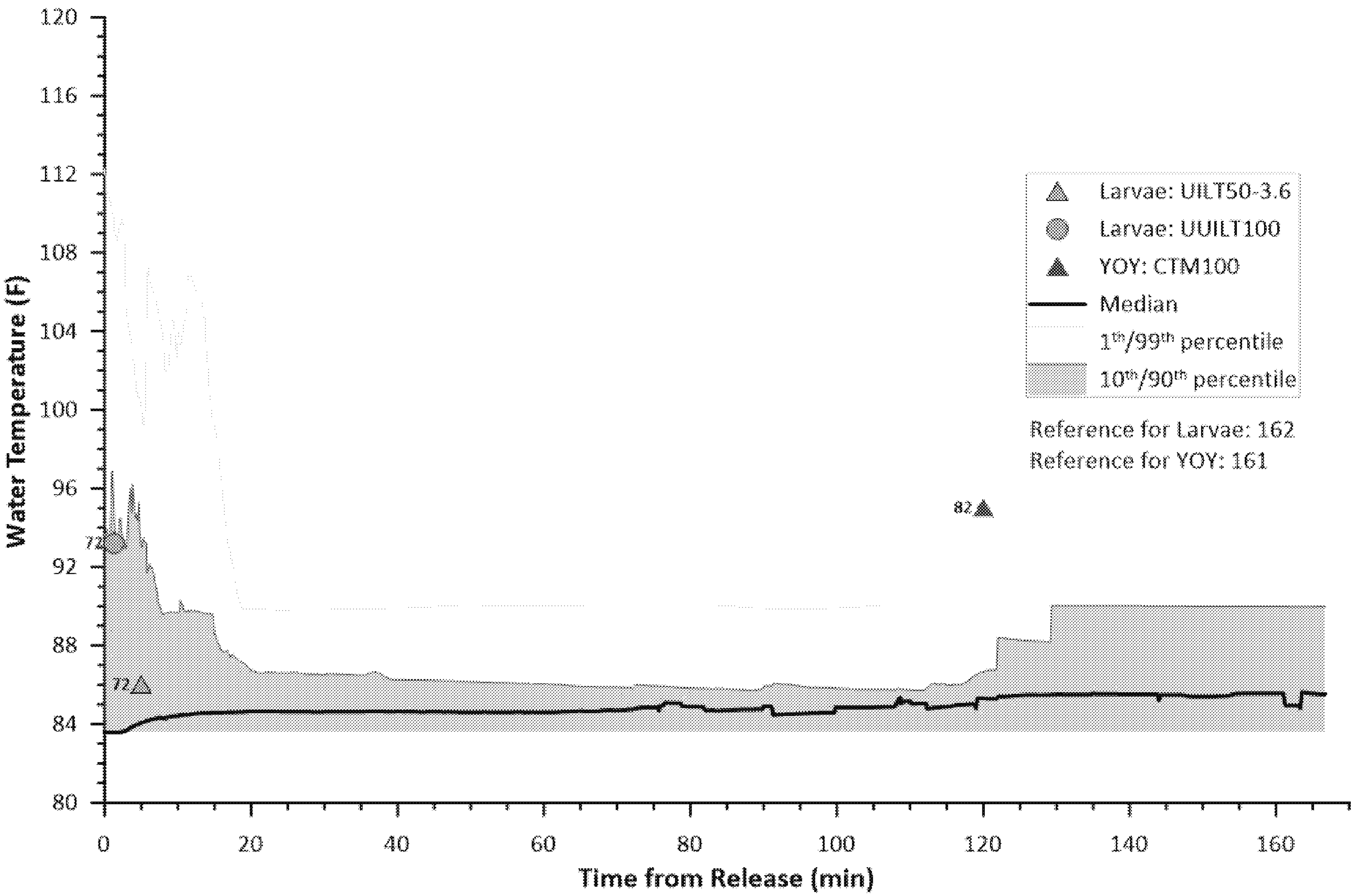


Figure 6-11 Short-term thermal tolerance of pallid sturgeon larvae and Upper thermal tolerance of YOY relative to temperature exposure based on particle tracking in the June 2006 model run. (Delta-T tolerance data are safe temperatures (TL50-3.6F). Data labels indicate test acclimation temperature).

White crappie

Spawning of white crappie occurs over an extended period from March to July. The eggs are demersal, colorless and adhesive and typically hatch in 27 to 93 hours depending on water temperature. Given their adhesive nature, eggs should not normally be part of the drift. The newly hatched fry begin to leave the nest after a few days where they are transported about by water currents. After approximately one month, the now juveniles retreat to the backwater nursery areas to avoid currents and actively feed and grow. No eggs and only 61 crappie larvae were collected in the two-year sampling effort in the vicinity of the LEC indicating that this area is not important spawning or nursery habitat for this species, or that spawning and nursery occurs in backwater areas away from the main channel. In either case, eggs and larvae of this species should have little potential for exposure to the LEC's thermal plume.

Unfortunately, there are no thermal tolerance data for white crappie larvae. However, the UILT for juvenile white crappie acclimated to temperatures comparable to those observed in the LMOR was 94.1°F (Table 6-1). These temperatures encompassed less than 1.0 percent of the LMOR volume in the vicinity of LEC (Figure 6-5) while drifting larvae would encounter these temperatures less that 25 percent of the time during the worst-case spring larval nursery period and none were exposed to these temperatures for more than 18 minutes (Figure 6-7). Hence, there appears little likelihood that white crappie larvae would experience exposures to lethal temperatures during drift.

6.3.1.2 Cold Shock

When exposed to a temperature gradient, juvenile and adult fish and other mobile organisms will tend to move to, and stay within, a preferred temperature range. The preferred temperature first selected by an organism depends on the initial acclimation temperature. Organisms continue to select progressively higher or lower temperatures until they reach their ultimate preferred temperature. This behavior provides a thermal environment, which approximates the optimal available temperatures for many physiological functions, including growth (Neill and Magnuson 1974). A species' ultimate preferred temperature (final preferendum) is usually near the upper end of its optimum range for growth (Brett 1971; Coutant 1975; Figure 6-9).

A consequence of thermal preference behavior is that fish in temperate and colder climates usually are attracted to heated water, such as may be caused by industrial discharges, during the fall, winter, and spring. When they are able to stay long enough to become acclimated to the warmer temperatures of the plume, there is potential for cold shock (i.e., a sudden decrease in temperature sufficient to cause severe thermal stress to aquatic organisms).

Information needed to assess the potential for cold shock associated with the complete shutdown of all units at the LEC was available for three of the six RIS selected for this assessment. In all cases, the LILT were less than the temperature exposures that would occur with complete shutdown of all units at the LEC (Figure 6-12 through Figure 6-15)[5]. Hence, there does not appear to be any potential for mortality associated with cold shock at LEC. Further, the likelihood that all units would be simultaneously shut down at the LEC is exceedingly low. For example, this never occurred over the 17-year period, 2002 – 2018; therefore, it does not appear that mortality from cold shock will be an issue at the LEC in the future.

[5] Guidance for interpreting Figures 6-16 through 6-22 is provided in Appendix C.

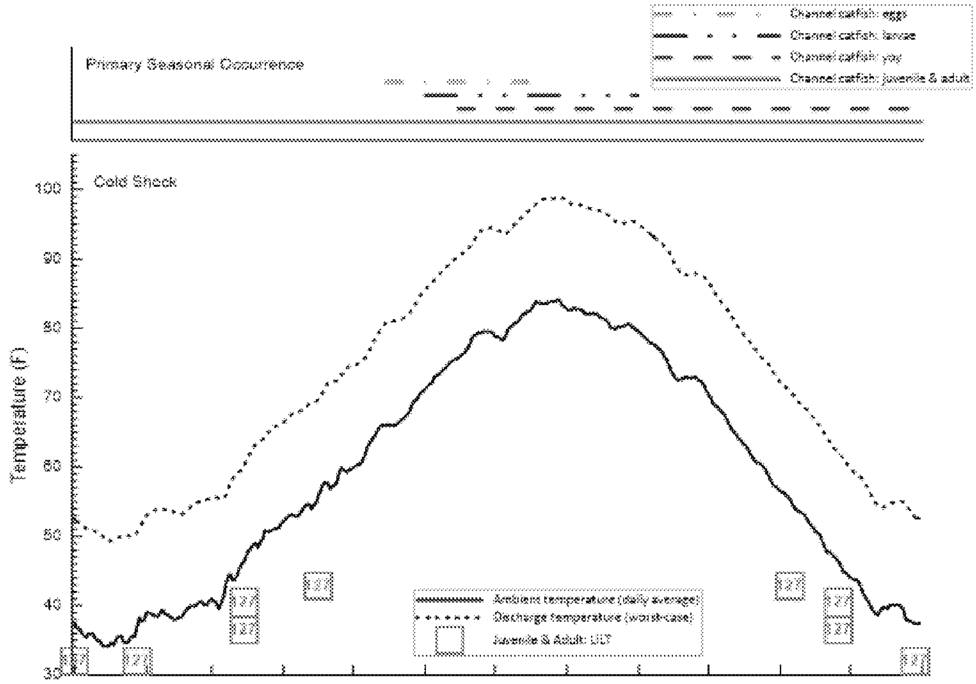


Figure 6-12 Thermal effects diagram relating to potential cold shock for channel catfish acclimated to maximum discharge temperatures and suddenly exposed to lower, ambient temperatures due to total instantaneous shutdown of all LEC generating units (numbers within thermal tolerance symbols are literature source codes).

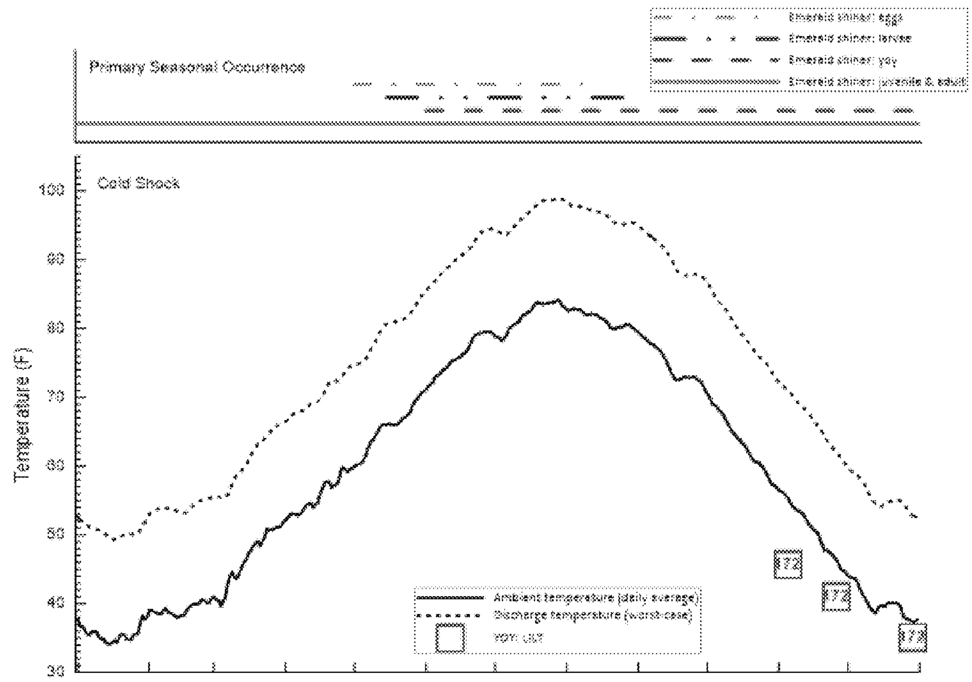


Figure 6-13 Thermal effects diagram relating to potential cold shock for emerald shiner acclimated to maximum discharge temperatures and suddenly exposed to lower, ambient temperatures due to total instantaneous shutdown of all LEC generating units (numbers within thermal tolerance symbols are literature source codes).

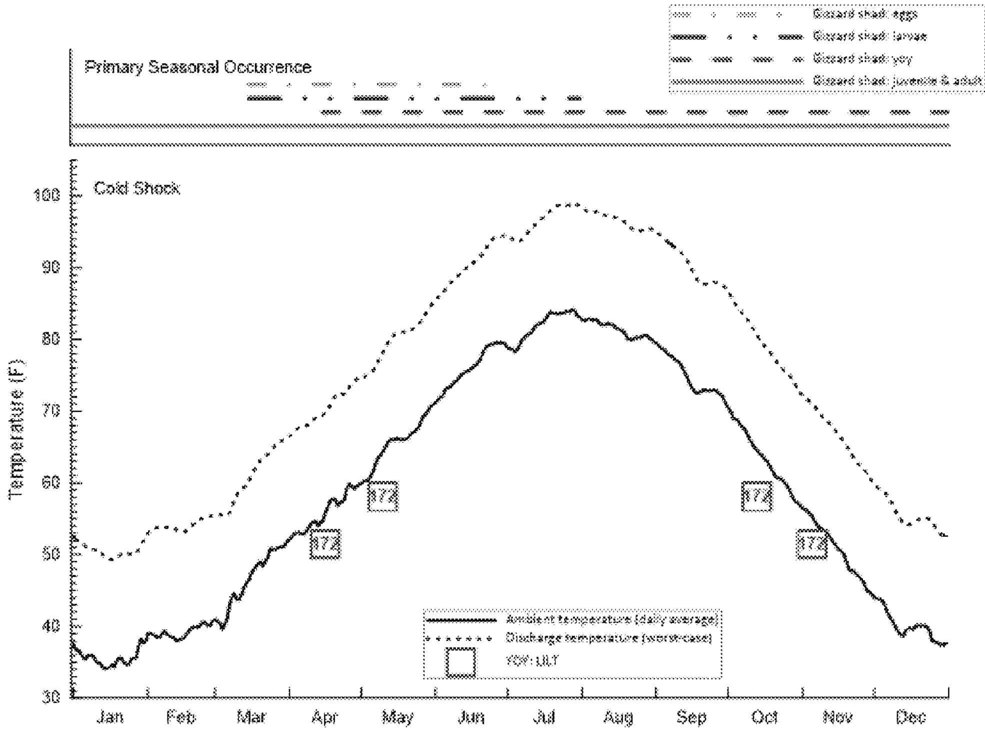


Figure 6-14 Thermal effects diagram relating to potential cold shock for gizzard shad acclimated to maximum discharge temperatures and suddenly exposed to lower, ambient temperatures due to total instantaneous shutdown of all LEC generating units (numbers within thermal tolerance symbols are literature source codes).

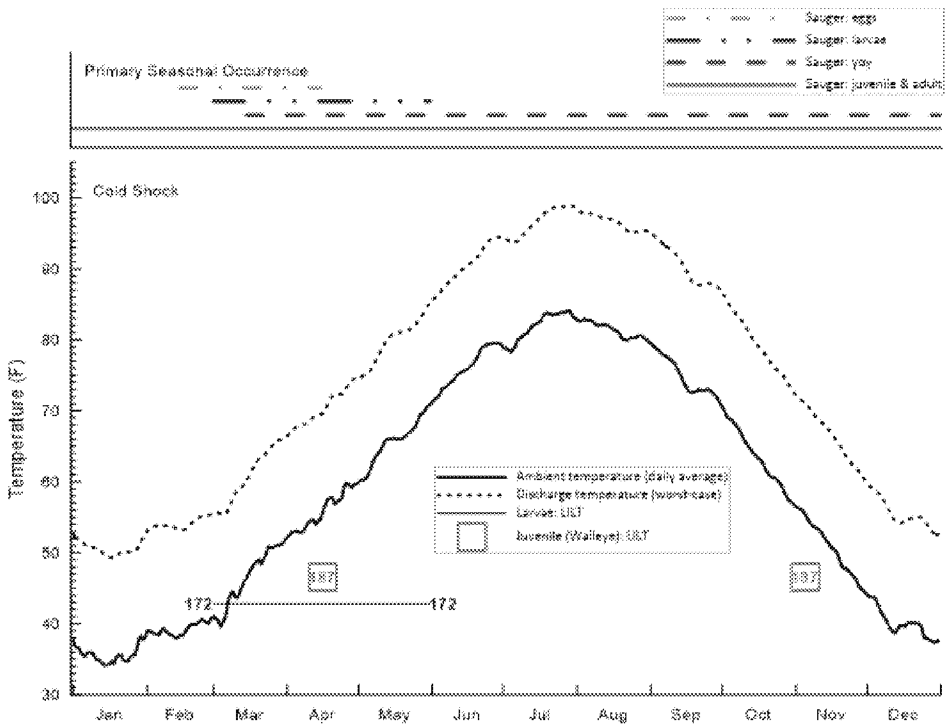


Figure 6-15 Thermal effects diagram relating to potential cold shock for sauger acclimated to maximum discharge temperatures and suddenly exposed to lower, ambient temperatures due to total instantaneous shutdown of all LEC generating units (numbers within thermal tolerance symbols are literature source codes).

6.3.2 Potential Effects Through Changes in Reproduction and Development

Thermal discharges can theoretically reduce reproductive success of species exposed to the plume by causing excessive shifts in the seasonal onset of spawning, disrupting normal egg development and hatch or reducing their growth and development. The potential for harm from such effects is a function of the spatial dimension of the habitat affected and the extent to which the affected zone is critical to the reproduction of the population. Since metabolic processes, such as body growth and egg maturation, are optimized for a limited range of temperatures, elevated plume temperatures can cause both increases and decreases in rates at which such processes occur.

Within the range of thermal tolerance there are temperature optima for metabolism controlling essential functions like growth and reproduction. Species are adapted to a range of temperatures in their environment over which they function at close to maximum physiological performance. As water temperatures increase above or below this range, physiological performance rapidly degrades. The optimum temperature range for growth is different for cold, cool, and warm water species, and also varies among developmental life stages of particular species. For example, the optimum temperature range for growth of most salmonids is between 54.5 °F and 61°F (NAS/NAE 1973); for American shad it is between 64°F and 75°F (Leggett and Whitney 1972; EA 1978a; IA 1978c), whereas the optimum temperature for growth of small juvenile striped bass is approximately 80°- 86.5°F (Kellogg and Gift 1983; Meldrim et al. 1974; Holland et al. 1971). The maximum value in a species' temperature range for optimal growth typically coincides with the organism's final temperature preference (Brett 1971; Coutant 1975).

Thus, there is a potential for thermal discharges to either increase or decrease an exposed organism's physiological performance and growth by shifting water temperatures toward or away from its optimum temperature range. Changes in physiological performance, in turn, have the potential to directly affect growth and reproduction, and indirectly alter the competitive ability of species and change community composition. Spawning can be influenced by an array of factors varying among species, including lunar cycles, photoperiod (i.e., duration of daylight), and water currents in addition to water temperature (Hoar 1969; Hardy 1978; Middaugh 1981; Conover and Ross 1982; Conover and Kynard 1984; Tewksbury and Conover 1987). The act of spawning may be relatively instantaneous for an individual organism and may coincide with a relatively narrow range of water temperatures. However, the conditioning that precedes the event and assures that mature individuals are at the appropriate stage of reproductive development when spawning temperatures occur can be a period of weeks or months (Hoar 1969; Hokanson 1977; Jones et al. 1976). Thus, reproductive condition in fish may represent a biological response to the range and average of environmental factors experienced during an extended period. Temperature is but one factor in a complex interrelationship of conditions conducive to spawning. These factors interact to assure that the time of spawning usually coincides with conditions (e.g., temperatures, food availability) conducive to development and survival of embryo and larval stages.

In temperate zone waterbodies, such as the LMOR, inter-annual variations in temperature can occur at any given date, especially during the period of rapid warming in spring. These variations may advance or delay the seasonal timing of spawning during warm and cool years, respectively. In addition, the rate of development and growth of eggs and larvae is, in part, dependent on water temperatures. In relatively warm springs, the effect of early spawning and accelerated development tends to result in a relatively early peak egg and larval season.

The assessment of the potential for the LEC's thermal discharge to adversely affect growth and development of each of the RIS is discussed in the following sections. Relevant life history information for each species summarized below is discussed in more detail in Section 6.2.

Channel catfish

Channel catfish spawn in nests most commonly between mid-May and mid-July in the LMOR (Figure 6-8). As the eggs are deposited in nests, eggs and the newly hatched larvae should experience very limited portion of the locally spawned individuals would be exposed to elevated temperatures from the LEC's thermal plume. For those individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-17).

Emerald shiner

Emerald shiners have a prolonged spawning period in the LMOR extending from late May through early July (Figure 6-8). Non-adhesive eggs are broadcast at night in shallow water near the surface where they sink to the bottom over rocky substrate, hard sand, or firm mud. Hence, eggs and the newly hatched larvae of this RIS should experience very limited exposures to elevated temperatures from the LEC's thermal plume. For those individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-18).

Gizzard shad

Gizzard shad appear to spawn in the vicinity of the LEC from approximately late March to late June (Figure 6-8). Spawning occurs in shallow water in relatively protected areas and eggs are adhesive and attach to the bottom. Hence, eggs and the newly hatched larvae of this RIS should experience very limited exposures to elevated temperatures from the LEC's thermal plume. For those individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-19).

Pallid sturgeon

Pallid sturgeon spawning in the LMOR generally should occurs from the end of April through May, based largely on observed spawning of shovelnose sturgeon (Figure 6-8). Preferred spawning habitat includes coarse substrate in the river currents in or adjacent to the main channel near wing dikes. Sturgeon eggs are adhesive and should not be exposure exposed to LEC's thermal plume. Newly hatched larvae migrate up into the water column and drift downstream for up to 13 days. After a few weeks, juvenile sturgeon settle into benthic habitats and are no longer part of the drift. For those rare individuals exposed, exposures to elevated temperatures could slightly advance development rates (Figure 6-20). The optimum temperature for growth of pallid sturgeon estimated from laboratory test data is about 72.3°F which is higher than ambient temperatures.

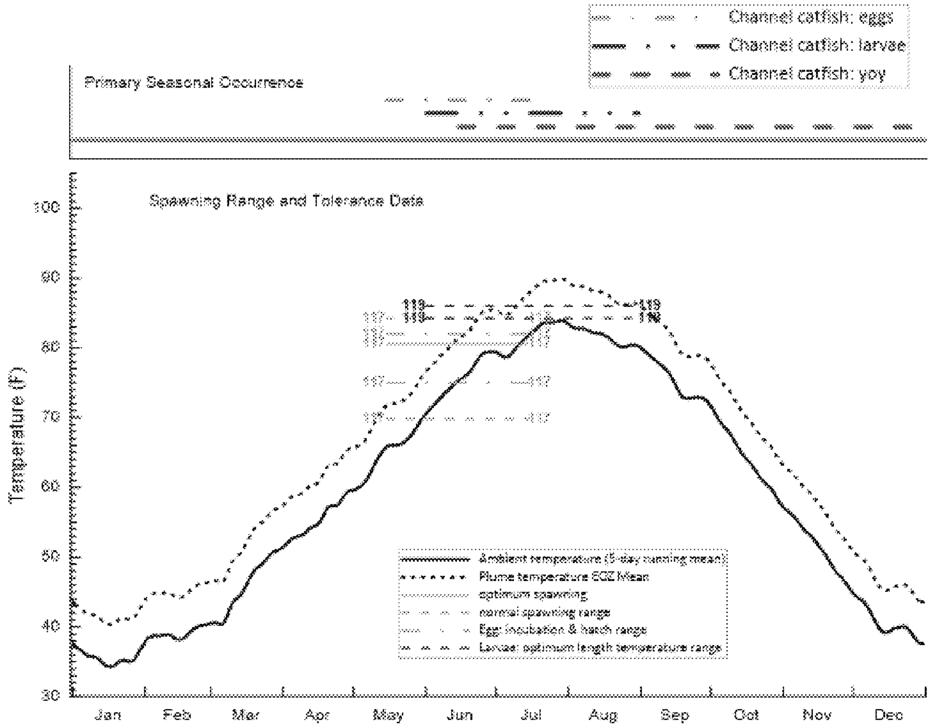


Figure 6-16 Reproductive success and growth data for channel catfish relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

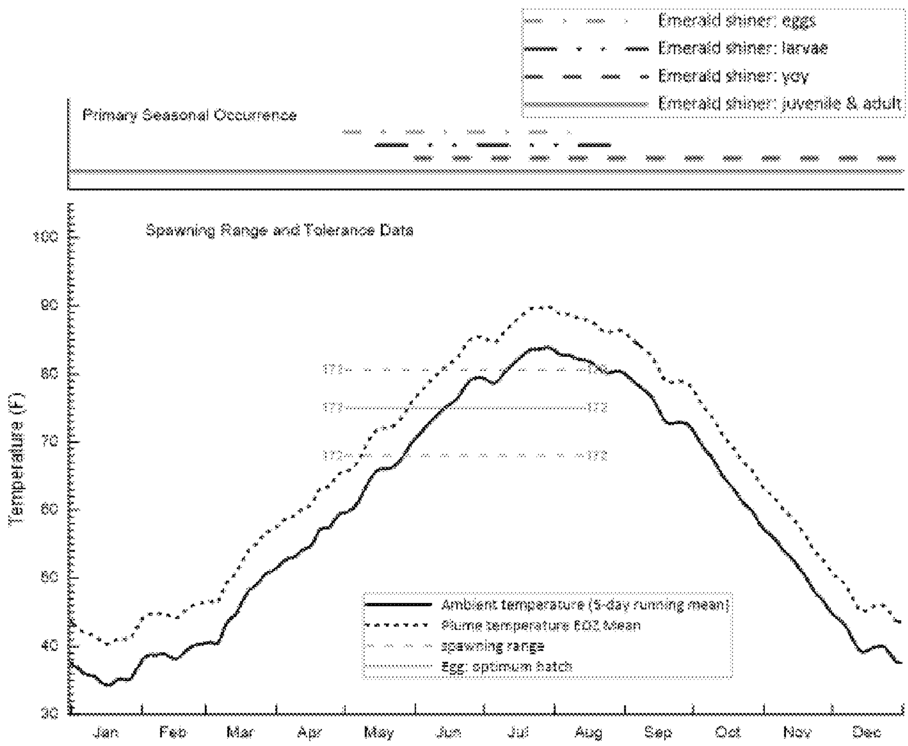


Figure 6-17 Reproductive success and growth data for emerald shiner relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

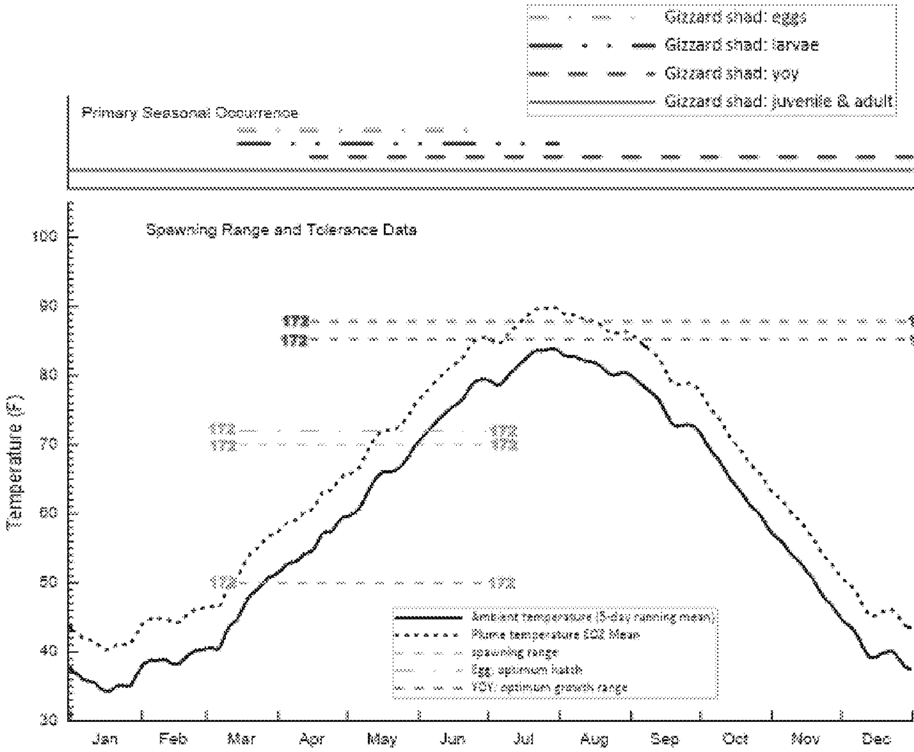


Figure 6-18 Reproductive success and growth data for gizzard shad relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

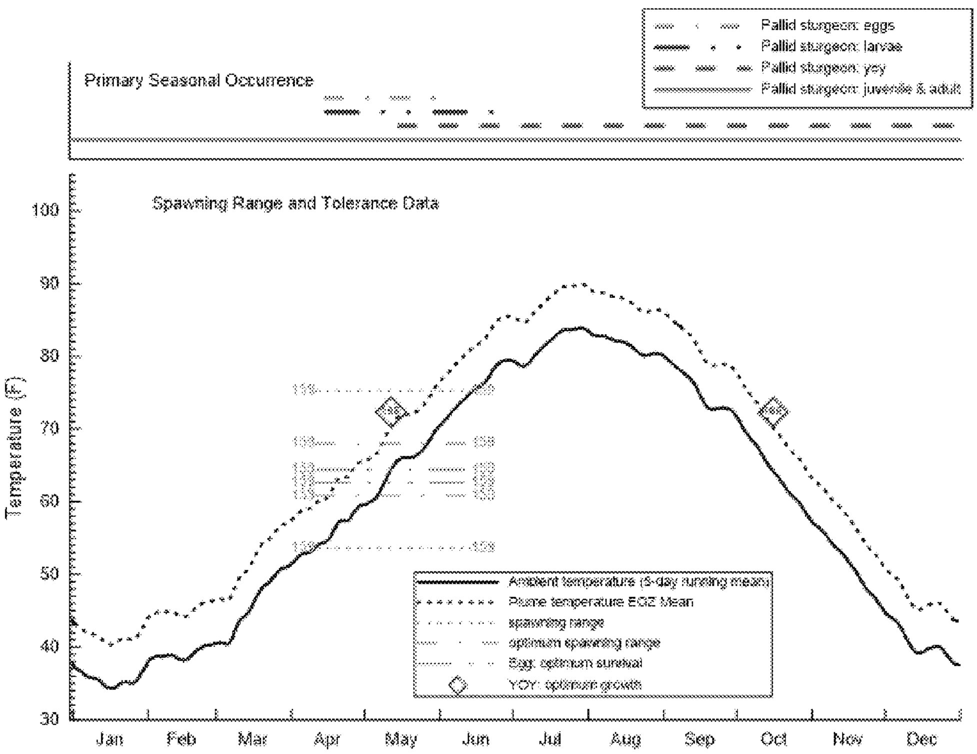


Figure 6-19 Reproductive success and growth data for pallid sturgeon relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

Walleye/sauger

Spawning of the two closely related species, walleye and sauger, typically occurs during February and March (Figure 6-8) in shallow shoreline areas, shoals, riffles, and the rock substrate at the base of dams. The demersal, adhesive eggs adhere to the substrate and should have minimal exposure to the LEC's thermal plume. A few days after hatch, the larvae swim up into the water column where they are transported by water flows to lakes or impounded river areas. For the later larval stages individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-21).

White crappie

White crappie spawning occurs from March to July (6-8). The demersal, adhesive eggs should not normally be exposed to elevated temperatures from the LEC's thermal plume. A few days after hatch the larvae swim up into the water column where they are transported about by water currents. After approximately one month, the now juveniles retreat to the backwater nursery areas to avoid currents and actively feed and grow where they should experience minimal exposure to elevated temperatures. For those few individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-22).

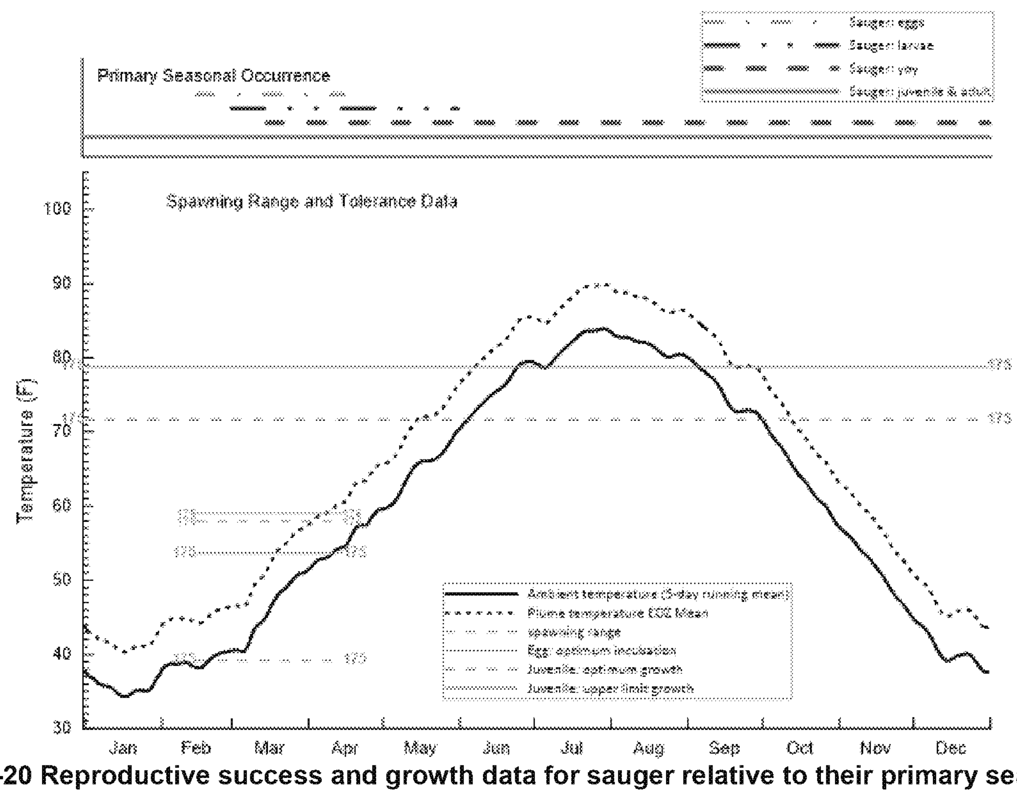


Figure 6-20 Reproductive success and growth data for sauger relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

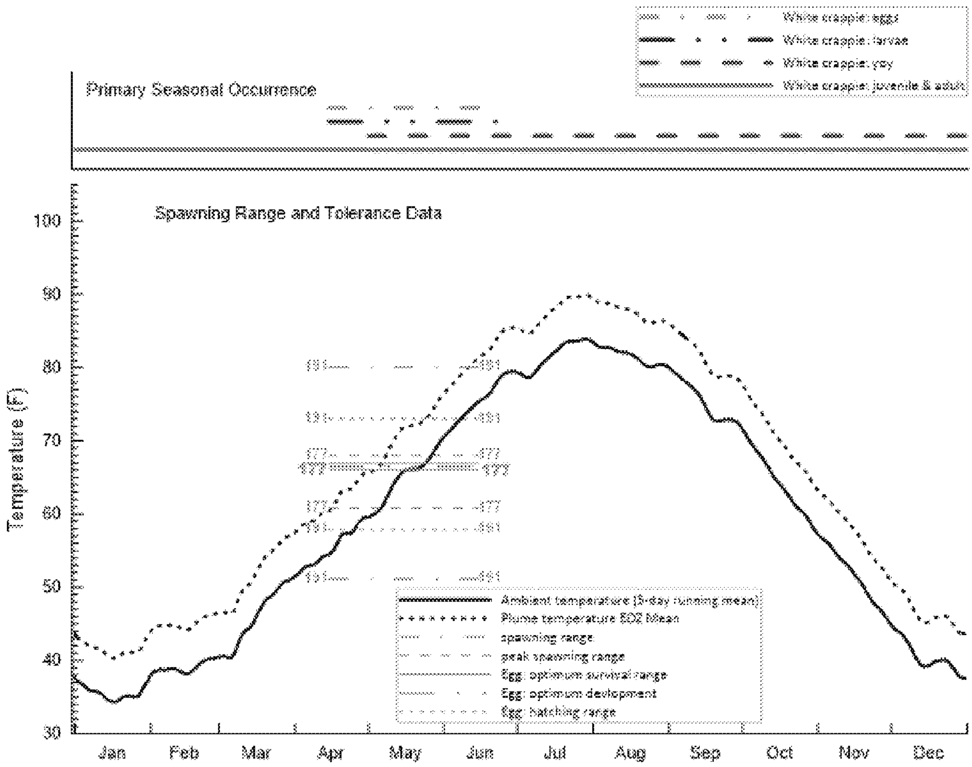


Figure 6-21 Reproductive success and growth data for white crappie relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

6.3.3 Potential Effects on Habitat Utilization and Migration

In the case of mobile species, organisms may adjust to their thermal environment behaviorally by movement along existing temperature gradients. When exposed to a temperature gradient, free-swimming juvenile and adult fish and other mobile organisms avoid stressful high temperature by moving through the gradient to water having lower temperatures (Meldrim et al. 1974; Neill and Magnuson 1974; TI 1976; EA 1978a). This is known as “temperature avoidance.”

Avoidance temperatures generally are close to, but slightly less than, the species UILT (Figure 6-9). The avoidance response precludes problems of heat stress from a thermal discharge for juvenile and adult fishes and other mobile organisms in open water systems such as the LMOR (USEPA 1976). The effect of localized elevations in temperature that approach thermal tolerance limits for such species is therefore generally limited to exclusion from otherwise usable habitat. Avoidance responses measured in the laboratory generally overestimate potential habitat exclusion in nature, because they do not account for long-term acclimation to elevated temperatures, or for other biological imperatives (e.g., feeding, migratory behavior) that may cause organisms to occupy areas at temperatures they might otherwise avoid. The focus of this assessment is on the potential for the LEC’s thermal plume to yield temperatures in excess of avoidances temperatures and, hence, block critical migratory pathways in the vicinity of the LEC.

For two of the RIS, channel catfish and emerald shiner, avoidance temperatures (Table 6-2) were higher than the temperatures observed in the vicinity of the LEC. Hence, the entire cross-section of the water column is available as a zone of passage for these species. For two other RIS, gizzard shad and white crappie, avoidance temperatures (Table 6-2) were occasionally exceeded as a result of the LEC’s thermal discharge. However, for both of these species, approximately half of the cross-sectional area in the vicinity of the LEC would still be available as a zone of passage under the worst-case conditions. Under more typical operations, no blockage would be expected for these species. Walleye and sauger are both cool water species and ambient temperatures frequently exceed their avoidance temperatures during summer (Table 6-2). At these times, these species would be expected move to cooler areas upstream or thermal refugia. Their use of areas near the LEC are limited to spawning migration during late winter and early spring when ambient temperatures average 40 to 50°F. At these times, exposure temperatures should be substantially lower than reported avoidance temperatures indicating no potential for blockage of migration. While estimates of avoidance temperatures for pallid sturgeon are not available, studies on mortality from thermal exposures suggest this may be more heat tolerant than originally thought species (Chipps et. al., 2010; 96-hour CTM of 91.4°F). This heat tolerance coupled with the fact that this species would most likely be found in deeper channel areas, suggests little potential for migratory blockage.

6.4 ASSSESSMENT SUMMARY

A Predictive Assessment is a process in which potential effects of the thermal discharge are calculated using information on the known characteristics of the thermal plume, together with a detailed three-dimensional hydrological model of worst-case conditions during the late spring spawning and nursery period and during the worst-case conditions during the summer. These two modeled scenarios demonstrated that, under worst-case conditions, the LEC's thermal plume quickly mixed with water in the LMOR causing temperatures to decline rapidly within 20 to 30 minutes and to approach ambient conditions within a few miles of the discharge. Elevated temperatures were largely restricted to areas along the southern shore of the LMOR and highest temperatures were found near the surface.

Table 6-2 Estimates of cross-sectional areas available for fish passage in the LMOR in the vicinity of the LEC's thermal discharge based on the July 2006 worst-case model.

RIS	Stage	Upper Avoidance Temperature (°F)	Acclimation Temperature (°F)	Percent of Cross-Section Available for Passage	References
Channel catfish	Juvenile & Adult	95	86	100.0	Cherry, D.S., K.L. Dickson, & J. Cairns, Jr. (1975)
Emerald shiner	Juvenile	107.6	NA	100.0	Ellis (1984) in: Wismer and Christie (1987)
Gizzard shad	Adult	93.2	80.6-86	52.3	Yoder and Emery (2003)
Pallid sturgeon		NA		NA	
Sauger	All	82	NA	0.0	Coutant (1977a) in: Wismer and Christie (1987)
White crappie	All	89.6	80.6-86	47.7	Yoder and Emery (2003)

The potential biological effects resulting from exposures to the worst-case thermal exposures was assessed on the following RIS:

RIS	Rationale
Channel catfish	Recreational species
Emerald shiner	Important food chain species
Gizzard shad	Important food chain species
Pallid sturgeon	Endangered species
Walleye/sauger	Recreational and temperature sensitive species
White crappie	Recreational and temperature sensitive species

These RIS were selected to reflect the biotic components of the indigenous community that were not deemed to be low potential for impact.

The magnitude of biological effects of elevated temperatures from the LEC's thermal plume was evaluated through four modes of potential effect. The results of these evaluations are discussed below.

Potential for Heat-Related Mortality

The potential for direct mortality from exposures to elevated temperatures was limited to eggs and larvae that could be carried into the LEC's thermal plume by river currents. Older, more motile stages, of each of the RIS can detect, and actively avoid, temperatures lower than those known to cause mortality. For most of the RIS, the egg and early larval stages are predominantly in areas where exposures to elevated temperatures from the LEC's thermal plume are limited rendering little likelihood of thermal mortality in these stages. Older larval stages could be exposed to elevated temperatures owing to their presences in the water column. To evaluate the potential for heat-related mortality for these life stages, temperature exposures were compared to reported lethal temperatures based on laboratory studies for each RIS. For most of the RIS, this comparison revealed little chance for lethal effects from the LEC's thermal discharge. For those RIS with reported lethal temperatures lower than exposure temperatures, exposures are of short durations and are limited to a small portion of the cross-section very near the LEC's discharge. Hence, mortality, if any, from LEC's thermal discharge is likely to be very small and occur very infrequently.

Potential for Cold-Shock Mortality

Cold shock can occur when fish, acclimated to the warmer temperatures of the plume, experience a sudden decrease in temperature associated with the cessation of generation at the LEC. Such cold shock can cause mortality if the temperature drop is sufficiently large. Evaluation of lower temperature tolerances of the RIS compared to potential for temperature drops in the vicinity of LEC revealed virtually no potential for cold shock from winter shut down. Further, analysis of the LEC operation over the past 17 years did not find a single instance where all four units at the LEC were simultaneously shut down.

Potential for Growth and Development Effects

The potential for sublethal effects through changes in growth and development was evaluated by comparing long-term temperature exposures at the edge of the ZID to optimal temperatures for spawning and growth. This evaluation revealed no evidence of negative effects on growth and development to any of the RIS from continual exposure to the LEC's thermal plume. In fact, such exposures are more likely to advance development and increase growth of the RIS leading to larger individuals at the end of the growing season.

Potential for Blockage of Migration

The potential for the LEC's thermal plume to block migratory pathways was evaluated by comparing temperature exposures to avoidance temperatures based on laboratory studies. This evaluation is based on the conservative assumption that the RIS will not pass through water at temperatures greater than reported avoidance temperatures. This evaluation documented that avoidance temperatures were higher than exposure temperatures for four of the six RIS indicating no potential for migratory blockage. For the remaining two RIS with some potential for migratory blockage under worst-case conditions, approximately half of the cross-sectional area in downstream of the LEC's discharge remained available as a migratory pathway.

Overall, the results of this predictive assessment provide evidence that the LEC's thermal discharge has little potential to result in an imbalanced indigenous community in the LMOR for two reasons. First, LEC's thermal discharge results in a calculated TDP value of less than 0.95 more than 99 percent of the time (indicating compliance with the current permit temperature limit). Such compliance assures protection of designated uses in the LMOR, including fish propagation. Second, potential effects under worst-case conditions appear to be small, of limited duration, and not likely to adversely affect the populations of RIS. None of these effects are of sufficient magnitude to jeopardize the continued protection of a BIC in the LMOR.

7. MASTER RATIONALE

This Demonstration for the LEC was prepared to address requirement D.3.b of the LEC's NPDES permit issued by the MDNR on May 3, 2017. More specifically, this Demonstration evaluates whether the LEC past and current operation has resulted in appreciable harm to the aquatic biota in the LMOR near the LEC. In addition, this Demonstation asseses whether the proposed alternative effluent limits for temperature will assure the protection and propagation of the BIC of the LMOR.

Ameren is requesting the following alternative temperature effluent limit for those rare instances (less than 1 percent of the time based on historical records) when there is a potential for exceedance of the water quality standards for temperature as a result of the LEC's thermal discharge. This alternative limit is designed to allow for the continued operation of the LEC while, at the same time, assuring the protection and propagation of a balanced indigenous community (BIC) in the LMOR:

- A TDP of greater than 0.95 will be allowed under conditions when the river flow is less than 40,000 cfs or ambient river temperatures are greater than 87°F;
- A TDP of greater than 0.95 will be allowed in no more than 6 percent of the days in any calendar year; and
- On any day where the TDP is greater than 0.95, the mixing zone must be less than 40 percent of the volume of the river as calculated by the equations in the permit.

Under § 316(a) of the CWA, a permittee may obtain a § 316(a) variance upon establishing, to the satisfaction of the permitting agency, that its thermal discharge, combined with other potential impacts on the aquatic biota, will assure the protection and propagation of the BIC in and on the receiving water body.

The Guidance Manual describes a BIC as one that is typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, and the presence of necessary food chain species. That is, the structure, function, and cyclical patterns typical of the waterbody's aquatic community should be maintained in the presence of the thermal discharge. The regulations also state that the BIC should not be simplified in structure or function and should not be dominated by pollution-tolerant species such as those tolerant of high temperatures or low dissolved oxygen. An "indigenous" community may contain species not historically native to the waterbody if they are present because of major irreversible modifications to the system or were deliberately introduced in wildlife management programs.

The purpose of this Master Rationale is to address whether the results of this Demonstration show that the LEC thermal discharge and requested § 316(a) variance meet the USEPA § 316(a) criteria for assessing appreciable harm.

7.1 INDICATORS OF APPRECIABLE HARM

The USEPA has determined that a community generally does not need to be protected from mere "disturbance," but rather that communities will be adequately protected if "appreciable harm" is avoided. The protection objective is typically to assure the sustainability of an indigenous community and protect its beneficial uses. In the terminology of Guidance Manual, this objective is prevention of "appreciable harm" which will assure the protection, propagation, and maintenance of the BIC. The criteria for evaluating appreciable harm include:

1. Presence of all trophic levels
2. Presence of necessary food chain species

3. Diversity
4. Capability to sustain itself
5. Lack of domination of pollution (heat) tolerant
6. No increase in nuisance species
7. Increase or decrease of indigenous species
8. No decrease in threatened and/or endangered species
9. No habitat exclusion due to temperature
10. Maintenance of a zone of passage
11. Change in commercial or sport species
12. No habitat former alterations
13. Magnitude and duration of any identifiable thermal effects
14. Sublethal or indirect effects
15. No thermal effects on rare or unique habitats
16. Presence of critical function zones within thermally exposed areas
17. Trends in the aquatic community
18. Interaction of the thermal discharge with other pollutants

These criteria focus the determination on population and community impacts. Still, demonstrating that the BIC is or will be assured in any receiving water body can be problematic since no operational definition of "balanced" is provided by the USEPA, and no quantitative standard for balance has ever been proposed. In this case, a weight-of-evidence approach using multiple lines of evidence for the LEC is used to evaluate the USEPA criteria and determine whether the thermal discharge has caused appreciable harm to the BIC in the receiving waterbody.

7.2 WEIGHT OF EVIDENCE RATIONALE FOR NO PRIOR APPRECIABLE HARM

Each of the appreciable harm criteria identified in Section 7.1 are addressed below using the results of the screening analysis and retrospective and predictive assessments conducted as part of this Demonstration.

1. *Presence of all trophic levels*

The area in the vicinity of the LEC thermal discharge was considered an area of LPI for phytoplankton, zooplankton, and habitat formers which are components of the lower trophic levels of the food chain. Benthic macroinvertebrate data showed they were equally abundant in the Upstream Reference and Thermally Exposed zones during all seasons of the year. Forage fish were abundant and comprised a large and similar portion of the fish assemblages in both the Upstream Reference and Thermally Exposed zones. Benthic feeders and top predators, while less abundant than forage species, similarly showed no difference between Upstream Reference and Thermally Exposed zones. The composition of the aquatic community in the Thermally Exposed zone shows the presence of the necessary trophic levels similar to the Upstream Reference zone, indicating that the structure of the community has not been adversely impacted by exposure to the LEC thermal discharge.

2. *Presence of necessary food chain species*

The fish collected during the current biological monitoring program represented feeding guilds from planktivores through top predators. Fish in each feeding guild were similarly abundant in the Upstream Reference, Thermally Exposed, and Downstream zones. As described above, forage fish and top predators comprised similar proportions of the fish community in all three zones. All the necessary food chain species are found in the Thermally Exposed and Downstream zones at the LEC.

3. *Diversity*

Diversity profiles for the both fish and benthic macroinvertebrates show that diversity in both assemblages was similar among the Upstream Reference, Thermally Exposed, and Downstream zones across gears and seasons. In the fish assemblage, forage and rough fish were the primary groups comprising the assemblages in the each of the three zones. Total fish abundance and dominant fish species were also similar across zones. In addition, the temporal analysis of the electrofishing data showed that fish assemblage diversity and composition has remained similar in both the Upstream Reference and Thermally Exposed zones over time. Thus, the evidence shows that diversity is being maintained and has not been adversely impacted as a result of exposure to the LEC thermal discharge.

4. *Capability to sustain itself*

The results of the predictive and retrospective assessments provide evidence that the biological community near the LEC is self-sustaining. The predictive analysis demonstrated the absence of significant mortality as a result of exposure to the LEC thermal plume for all life stages of the selected RIS, even under worst-case exposures. Similarly, RIS growth and development would not be negatively affected by the LEC thermal discharge. As a result, no adverse effects on the ability of the populations exposed to the LEC thermal discharge to sustain themselves are expected. This conclusion is supported by the retrospective analysis which showed multiple year classes and life stages evident in fish assemblage in the current study, no substantial shifts in the fish community over time, and no substantial changes in the current fish or benthic macroinvertebrate assemblages between the Upstream Reference and Thermally Exposed zones.

5. *Lack of domination of pollution (heat) tolerant*

Both fish and benthic macroinvertebrate assemblages were dominated by heat tolerant taxa in both the Upstream Reference, Thermally Exposed, and Downstream zones and the abundance of heat tolerant taxa was similar between zones. In general, heat sensitive taxa comprised only small proportions of the assemblages in each zone. The temporal analysis of the fish data show that heat tolerant taxa have not increased in the Thermally Exposed zone over time and remain at the similar proportions as in the Upstream Reference zone.

The temporal and spatial retrospective analyses provide evidence that pollution/heat tolerant and nuisance species have not become a dominant part of the fish or benthic macroinvertebrate assemblages due to the LEC thermal discharge.

6. *No increase in nuisance species*

Species of Asian carp, including bighead, silver, and grass carp, are among the most notable non-native, nuisance species now present in the LMOR. The invasive Asian carp have become increasingly abundant throughout the entire LMOR through a process of range expansion following their accidental escape into the Mississippi River basin, which is clearly not due to the LEC thermal discharge. Many of the fish classified as rough fish, including the Asian carps, common carp, and possibly gizzard shad can be considered nuisance species. The proportion of rough fish in the Upstream Reference, Thermally Exposed, and Downstream zones was shown to be similar. The proportion of rough fish in the Upstream Reference and Thermally Exposed zones has also remained similar over time. Hence, the LEC thermal discharge has not caused an increase in nuisance species.

7. *Increase or decrease of indigenous species*

The bed, banks, and flow regime of the Missouri River have been modified and managed for navigation and flood control over many decades prior to the start of the LEC thermal discharge. Such river-wide modifications and loss of the natural riverine flow regime and habitats have greatly influenced the abundance of native species and affected the overall composition of the fish community. It has been reported that many native fish species are now rare, uncommon, or decreasing in abundance across part or all of their previous range as a result of this extensive habitat modification (NRC 2002). In many reaches of the river, the abundance of non-native species has become greater than that of native species because of their greater tolerance for river-wide changes, modifications and loss of the natural riverine flow regime and habitats. These changes to native fish populations have occurred in response to irreversible river modifications that are unrelated to the LEC thermal discharge and would have resulted in the absence of the discharge altogether.

The temporal retrospective analysis shows that the fish assemblage represented in electrofishing samples was comprised primarily of rough fish in both the Reference and Thermally Exposed zones both in the historical as well as recent studies. The overall composition of the electrofishing assemblages was similar between zones and over time. These results demonstrate that the LEC thermal discharge has not resulted in a decrease, locally or in the LMOR, of indigenous species.

8. *No decrease in threatened and/or endangered species*

The pallid sturgeon is the only federally endangered species potentially in the vicinity of the LEC. Available data suggests that this species is declining throughout the Missouri River due to factors such as upstream dam and reservoir construction, reduced river water velocities and low bottom dissolved-oxygen levels. These conclusions demonstrate that the river-wide decline of pallid sturgeon is unrelated to the LEC's thermal discharge. Further, there is no evidence that LEC's thermal discharge has eliminated designated critical habitat areas for pallid sturgeon in the LMOR.

9. *No habitat exclusion due to temperature*

Under typical plant operation, four of the six RIS would experience no habitat exclusion. Walleye and sauger are not typically abundant in the LMOR near the LEC during the summer period, since ambient river water temperatures are above their thermal tolerance limits. Under worst-case conditions, both gizzard shad and white crappie may experience some habitat exclusion along the southern shoreline just downstream of the LEC. Ample alternate habitat exists for gizzard shad and white crappie in the vicinity of the LEC that would offer temporary refuge from the elevated temperatures. For pallid sturgeon, little to no habitat exclusion is expected due to their expected heat tolerance. The predictive assessment demonstrates that substantial areas of habitat would not be excluded for all RIS.

10. *Maintenance of a zone of passage*

Under typical plant operation, four of the six RIS would have the entire river cross-section available as a zone of passage. Under worst-case conditions, gizzard shad and white crappie would have approximately half of the river cross-section available as a zone of passage. Walleye and sauger are only expected to be in the vicinity of the LEC during spawning migrations which occurs during cooler times of the year. At these times, no blockage of passage is expected for these species. The predictive assessment demonstrates that a zone of passage would be maintained at all times for all RIS.

11. Change in commercial or sport species

The retrospective spatial analysis shows the abundance of game fish is approximately equal in the Reference, Thermally Exposed, and Downstream zones, combining all seasons and gear types. Game fish also comprise approximately equal percentages of all fish in each of the three zones. The temporal analysis shows that there was a slightly higher abundance of game fish collected in the historical Thermally Exposed zone electrofishing study than the present study. These analyses provide no evidence that the LEC thermal discharge has resulted in a change or decrease in the number of sport or game fish.

12. No habitat former alterations

The screening analysis concluded that the LMOR near the LEC was found to be an area of LPI for habitat formers due to the river's velocity, turbidity, and silty substrate which were limiting factors to the colonization and development of habitat formers. These conditions, along with physical alterations to the river shorelines and persistently unstable substrate conditions demonstrates that the absence of habitat formers in the vicinity of the LEC is not related to the discharge and, even in the absence of the discharge, habitat formers would not be able to colonize the area.

13. Magnitude and duration of any identifiable thermal effects

The retrospective and predictive assessments show that there are no discernable effects related to the LEC thermal discharge outside of the Discharge zone, which is within the allowable mixing zone. The hydrodynamic modeling of various scenarios, including the most extreme discharge scenario over the last 17 years of LEC operation, shows that the elevated temperatures in the thermal discharge are rapidly attenuated after the confluence of the discharge with the Missouri River. At the most upstream end of the Thermally Exposed zone, mean daily temperatures within the thermal plume are, at most, 6°F above ambient. In addition, the thermal discharge is typically less than 5 percent of the Missouri River flow and the duration of any exposures are usually brief, transiting through the upper portion of the thermal plume within an hour and a half.

14. Sublethal or indirect effects

These types of effects are primarily related to reproduction and growth and may be experienced should the river temperatures fall outside of the range of optimum spawning and growth temperatures for individual species. The predictive assessment shows all RIS may experience slightly earlier spawning and increased growth rates under the worst-case conditions associated with the LEC thermal discharge. Little to no difference in spawning or growth rates are expected under typical plant operating conditions. These results demonstrate that no adverse effects on reproduction or growth are associated with the LEC thermal discharge.

15. No thermal effects on rare or unique habitats

There are no habitats in the Thermally Exposed or Downstream zones designated as "unique or rare" for this portion of the LMOR.

16. Presence of critical function zones within thermally exposed areas

There are no critical function zones (e.g., critical spawning and nursery areas) present within the Thermally Exposed and Downstream zones for any RIS. The predictive assessment also showed that there would only be minor episodic exclusion from a small area of habitat within the Thermally Exposed zone and only under worst-case exposures.

17. Trends in the aquatic community

The retrospective analysis shows diversity was similar over time and between the Upstream Reference and Thermally Exposed zones. Both Upstream Reference and Thermally Exposed zones showed similar composition over time with the community being dominated by rough fish (e.g., Asian carp, common carp, gizzard shad) with game fish representing the next most dominant group. Most of the fish assemblage in the Upstream Reference and Thermally Exposed zones were heat tolerant and they comprised a similar percentage of the assemblage over time and among zones. A standardized difference test combining the results of multiple community metrics showed that the differences between the zones was inconsequential and demonstrating no appreciable harm to the aquatic community.

18. Interaction of the thermal discharge with other pollutants

In addition to the direct effects on the aquatic organisms, heat added to aquatic environments has the potential to impact the BIC through the additive or synergistic effects of heat combined with other existing thermal or other pollutants in the receiving waters. In the LMOR, there are no other sources of thermal discharges anywhere near the LEC such that there would be any overlaps of thermal plumes or their effects. Hence, there is no potential for additive or synergistic effects of the LEC's thermal discharges with any other thermal discharges.

Thermal discharges, alone, have the potential to interact with other pollutants and other water quality parameters through various physical, chemical and biological processes to increase their negative effects on aquatic ecosystems. The existence and magnitude of such effects will depend on site-specific conductions, including the magnitude of pollutant concentrations and degraded water quality conditions as well as the magnitude, spatial extent and frequency of occurrence of elevated temperature exposures.

The area of the LMOR near the LEC is considered degraded as a result of nutrient loadings, toxic chemical contamination, bacterial contamination and low dissolved oxygen concentrations (Section 2.1). The potential for the LEC's thermal plume to exacerbate each of these known problems is discussed below.

<u>Nutrients</u>

The LMOR near the LEC is known to contain elevated levels of nutrients, including organic nitrogen, nitrate, total phosphorus, and ortho-phosphorus, principally from upstream non-point source agricultural runoff. These nutrients can result in excessive algal growth leading to wide swings in dissolved oxygen levels and reductions in SAV through increased turbidity.

The areas of the LMOR exposed to elevated temperatures is relatively small and the water containing these nutrients pass through these areas rapidly (< 2 hours). Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of algal growth and result in greater adverse impacts to the LMOR.

<u>Chemical Contaminants</u>

The LMOR near the LEC is known to contain elevated levels of pesticides, PCBs and mercury. The first contaminant is most likely from upstream non-point source agricultural runoff whereas the latter two contaminants are most likely from industrial discharges to the LMOR. Each of these contaminant categories tend to accumulate in sediments.

The sediment areas of the LMOR exposed to elevated temperatures are relatively small and exposure temperatures are reduced owing to dilution. Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of contaminant uptake and result in greater adverse impacts to the LMOR.

Bacterial Contaminants

The LMOR near the LEC is known to contain elevated levels of bacteria from human sources including *Escherichia coli*. These anthropogenic bacteria most likely come from sewage treatment facilities and urban runoff in the area. Currently, the MDNR lists the LMOR in the vicinity of the LEC as impaired as a result of *E. coli* contamination.

As with nutrients, the areas of the LMOR exposed to elevated temperatures is relatively small and the water containing these bacteria pass through these areas rapidly (< 2 hours). Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of bacteria growth and result in greater adverse impacts to the LMOR.

Dissolved Oxygen Concentration

The LMOR near the LEC is known to occasionally have dissolved oxygen (DO) concentrations less than the MO Water Quality Standard of 5 mg/l. These low DO concentrations can be attributed to loadings of nutrients and other organic materials from a variety of sources and most commonly occur during the warmer months of the year.

Elevated temperatures can yield lower DO levels through one of two processes. First, the solubility of oxygen in water is inversely related to water temperature. Hence, increases in temperature can result in off gassing of oxygen when DO concentrations are at saturation levels. However, since DO levels in the LMOR are rarely at saturation levels, this process is not likely to have any effect on DO levels in and adjacent to the LEC's thermal discharge. Second, elevated temperatures can increase the chemical and biological processes that require oxygen and result in lower DO levels in the water. However, as is the case with nutrients and bacteria, the area of the LMOR exposed to elevated temperatures is relatively small and the water containing the oxygen passes through these areas rapidly (< 2 hours). Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of oxygen consumption and result in greater adverse impacts to the LMOR.

These conclusions regarding the effects of the LEC's thermal discharge on DO levels in the LMOR are supported by the results of DO monitoring conducted in the vicinity of the LEC as part of the biological monitoring studies. Cumulative percent plots of the DO measurements collected during July and August, when water temperatures are highest, reveal no demonstrable differences in the distribution of DO levels across the zones of thermal exposure (Figure 7-1). This further supports the conclusion that the LEC's thermal discharge is not resulting in lower DO levels in the LMOR.

Overall, the results of this analysis demonstrate that the LEC's thermal discharge will not exacerbate existing environmental issues in the LMOR through additive or synergistic effects of the heat discharged combined with other existing thermal or other pollutants.

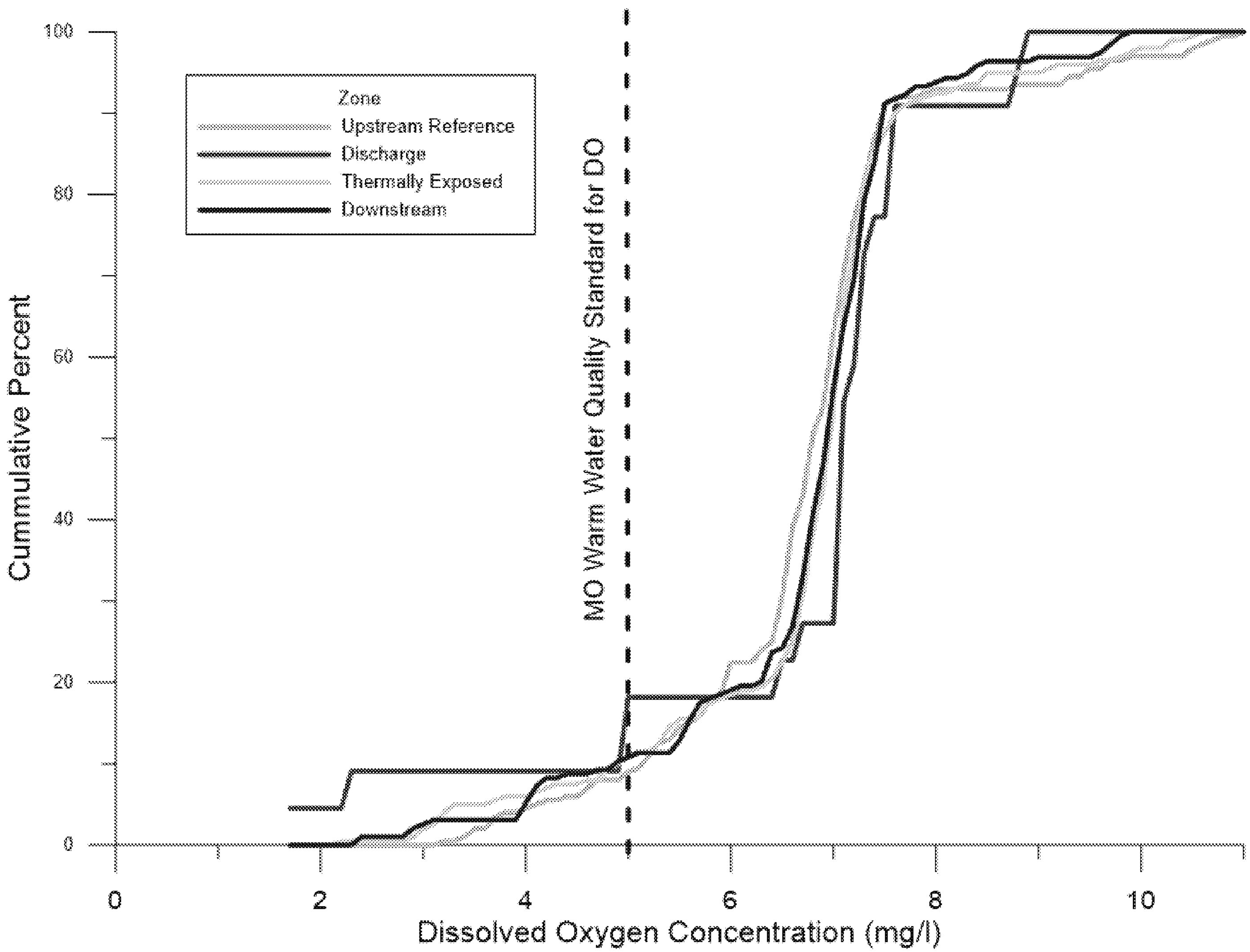


Figure 7-1 Cumulative percent of measured dissolved oxygen concentrations from July and August above and below the MO water quality standard for dissolved oxygen.

7.3 OVERALL CONCLUSIONS

The screening analysis and the retrospective and predictive assessments were used to evaluate 18 decision criteria for assessing appreciable harm identified by the USEPA. In each case the available data and analyses demonstrate that the decision criteria were satisfied indicating that no prior appreciable harm has occurred as a result of the LEC's ongoing thermal discharge and the requested alternative temperature effluent limitation (§ 316(a) variance) will assure the protection and propagation of the BIC in the LMOR.

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APPENDIX A
LABADIE ENERGY CENTER § 316(a) STUDY PLAN AND ADDENDA

APPENDIX B
RETROSPECTIVE ASSESSMENT TABLES

APPENDIX C
RIS PREDICTIVE EVALUATION METHODS